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Evaluation of the Effectiveness of Child Safety Restraints

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16. Abstract

The goals of this study were to better establish the relationships between proper and improper usage of safety seats in crashes and the resulting injury levels and mechanisms and to establish measures of the distance from home that the children were when these accidents occurred. Using police reported accident data and supplemental information obtained through telephone interviews with parents/drivers of these children, the following conclusions were drawn: Almost half of the accident involved children were involved in crashes within 5 miles of their home and 70 percent were involved within 10 miles. Severe crashes were as likely to occur close to home as they were farther from home. Overall, safety seats with easy to use designs were more likely to be properly used. Seats with separate shields or that required tethers were least likely to be correctly used. Serious injuries that were received by children in properly used seats were likely to be caused by intrusion or flying objects. Other findings show that lap held children are very vulnerable to serious and fatal injuries with the front center position being the most dangerous. Safety belts were shown to be very good protection for children when used in the rear seat. When compared to unrestrained and lap held children, lap belts reduced moderate to fatal injuries by 43 percent. Lap/shoulder belt combinations reduced these injuries by 32 percent. Gross misuse and partial misuse of safety seats resulted in 45 and 44 percent reductions in moderate to severe injuries while properly used seats showed a reduction of 68 percent.

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EXECUTIVE SUMMARY

This study consisted of an effort to utilize a data set established by conducting telephone interviews with parents and/or drivers of accident involved children in order to better examine the effectiveness of safety seats in crashes. The interviews provided information on the brand name and models of seats in use and how they were being used at the time of the crashes as well as injury information. The primary goal of this project was to better establish the relationships between proper and improper usage of seats and resulting injury levels and mechanisms. Another goal was to use a subset of these accidents to establish measures of the distance from home that the children were when these crashes occurred. This distance was measured on maps between the accident location and the child's address.

The basic conclusions drawn from the analyses of distance from home measures are that 14 percent of the children were involved in accidents within a mile of their home, half of the children were involved within 5 miles of home and 7 out of 10 children were involved in accidents within 10 miles of home. The conception that restraints are not used on short trips close to home is supported by the finding that the highest rate of unrestrained children was for those children within five miles from home. Danger exists for these children since severe crashes are just as likely to occur close to home as they are farther away.

Due to problems inherent in classifying the safety seats in use as to their proper/improper usage, one-third of the seats were classified as "unknown" usages. For those seats where a classification was possible, large differences were found between different types of seats and their levels of misuse.

Infant carriers were more likely to be used correctly than were convertible seats used for infants. Interestingly, infant convertible seats were more likely to be partially misused but infant carriers were five times more likely to be grossly misused. For toddlers, the highest level of proper use was for harness/shield combinations and the highest level of misuse was for tethered models. Seats with a harness plus a separate shield were also highly likely to be misused. Among the booster seats, the shield type boosters were three times more likely to be properly used than were the harness type boosters. As shown by the following summary table, properly used safety seats were the most effective mode of restraint for preventing injuries. For those seats where proper/improper usage was known, properly used safety seats reduced moderate,

severe and fatal injuries by 76 percent. Partially and grossly misused seats reduced these injuries by 58 and 59 percent.

Moderate to Fatal Injury Rates for
Different Restraint Types

Restraint	N/Inj.	Inj. %	Effectiveness
None	2783 515	18.50	**
Lap Held	941 107	11.37	-38.5
Lap Belt	803 63	7.85	-57.6
Lap & Shoulder Belt	265 25	9.43	-49.0
CR Proper	476 21	4.41	-76.2
CR Gross Misuse	131 10	7.63	-58.8
CR Partial Misuse	910 71	7.80	-57.8
CR Unknown Proper	922 67	7.27	-60.7

**Percent difference from no restraint injury level. All differences are significant.

When the different types of seats are looked at separately, the general trend among the types is for the properly used seats to show a higher proportion of no or minor injuries and a smaller proportion of moderate injuries. The severe head/fatal injuries are so spread out among the different types of seats that no trends could be established. Overall, children in properly used safety seats were more likely to receive their injuries from sources beyond control of the seats themselves, such as intrusion or flying objects, whereas children in improperly used seats are more likely to receive their injuries in ways that the seats were designed to prevent such as from striking the vehicles interior or contacting the restraint system.

These data show that lap held children are very vulnerable to serious and fatal injuries. Overall, lap held children had a severe head/fatal injury rate of 3.4 percent. The front center position, with a 9.8 percent severe head/fatal injury rate was shown to be the most dangerous position for lap held children. Lap held children were vulnerable to injuries resulting from striking the vehicles' interior, contact by other occupants, and by ejection, although lap held children in the rear seat fared relatively well.

When safety belts were examined, they were shown to be very good protection for children. When compared to safety seats, safety belts allow more children to strike the vehicle's interior than do properly used safety seats and they produce more injuries from contact with the restraint system itself. Safety belts do, however, compare favorably with misused safety seats both in terms of preventing injuries and in terms of the mechanisms associated with those injuries that do occur.

When the injury distribution for unrestrained children was compared to those for children in safety belts and safety seats, all modes of restraints were shown to be effective in reducing severe head and fatal injuries. Overall, lap belts reduced these injuries by 54 percent and lap and shoulder belts showed a 59 percent reduction. Properly used safety seats showed a 69 percent reduction even with some very unusual accidents. Grossly and partially misused seats showed reductions of 44 percent and 92 percent as compared to no restraint. Better methods for classifying proper/improper usage may have changed these figures.

The center rear position was found to be the safest position for children regardless of restraint usage. In general, any rear seat position is safer than any front seat position for any given restraint/nonrestraint mode. Interestingly, severe head/fatal rates for no restraint, safety belts and safety seats were all lower for the rear seat than for the front in less severe crashes. The same trend held true for no restraint and safety belts in the more severe crashes as well. For safety seats, however, safety seats had a much higher severe head/fatal injury rate for the rear seat than for the front. Possible explanations for this unexpected finding may include usage patterns of different restraints for different age children and unusual crash circumstances.

The issues of proper/improper safety seat usage and how this relates to the relationship of the child to the driver and how the seat was acquired were also explored. The vast majority of children (78%) were being driven by the parent. Children being driven by their parents were more likely to be buckled up than those driven by a nonparent. This was consistent with the provisions of the North Carolina child restraint law at the time. For children in safety seats, those being driven by a parent were twice as likely to be riding in a properly used seat than were those driven by another relative (29% versus 15%). The number of non-relative children in seats where proper/improper usage was known was too small for comparison.

The method of seat acquisition also had an effect on proper/improper usage rates. Seats that were bought used, presumably without any instructions, had the lowest rate of proper use (11%) and the highest gross misuse rate (33%). Seats that were acquired new, whether purchased by the parents or received as a gift from someone else, were more likely to be used properly than seats bought used, but even with the availability of manufacturers' instructions, only about 30 percent of the new seats were properly used. Seats that were on loan from a friend or relative were used correctly more often (36%) than seats purchased used. The highest proportion of proper use (45%) was for seats rented through a local safety seat rental program. Whether this is due to the instructions received through the rental or to the high proportion of infant carriers among the rental seats is not known.

PREFACE

The author would like to take this opportunity to express sincere appreciation to those who have assisted in this research effort.

Cooperation by the North Carolina Department of Transportation, Division of Motor Vehicles made the original data collection effort possible. The Traffic Engineering Branch further cooperated in the supplemental data collection efforts through the use of their collection of maps.

Appreciation is expressed to the U.S. Department of Transportation, National Highway Traffic Safety Administration, Office of Driver and Pedestrian Research which was the project's sponsor. Assistance from Dr. John Eberhard, the Contracting Officer's Technical Representative, was of great benefit.

Within the Highway Safety Research Center, special appreciation is expressed to Linda Rudisill who made the "distance from home" measurements, Tamara Fischell who performed the computer programming, Dick Stewart who assisted with the analyses and to Peggy James and Teresa Parks who typed the report.

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INTRODUCTION

The need for occupant restraint systems in motor vehicles is readily apparent to those who are aware of the basic physics of a crash or sudden stop. On impact, the car begins to crush and slow down. Persons inside the car continue to move forward at the same speed that the car was traveling. Within 1/10 of a second, the car has come to a stop, but the unbelted occupants are still moving forward until they slam into the dashboard or windshield or get thrown out of the car. A great many fatalities and serious injuries are caused by people being ejected from the car where they are likely to hit hostile objects--rock, trees, pavement, etc. Safety seats and belts reduce the likelihood of death or serious injury by holding the child or adult away from the dashboard and inside the passenger compartment where it is safer and allows them to "ride down" the crash with the car.

Many studies have been conducted which address the injury reduction potential of restraint systems. Due to differing data bases and possible biases inherent in the data, effectiveness estimates for safety seats have ranged from 40 percent to 90 percent effectiveness in reducing fatalities and from 17 percent to 74 percent effective in reducing injuries (Kahane, et al.).

Safety seat effectiveness estimates based on state or national accident files are generally limited in their ability to distinguish the protective value of properly used safety seats versus seats that are not used correctly. The degree to which the misuse of safety seats reduces their effectiveness in preventing fatalities and serious injuries is of great concern to child passenger safety advocates since recent studies have shown that the majority of seats in use are not being used correctly. In an observational survey, Shelness and Jewett (1983) found that 75 percent of 2323 safety seats examined in parking lots were installed in cars incorrectly, that is, not according to manufacturers' instructions.

A more extensive survey was conducted by Cynecki and Goryl (1984) where children were observed in cars in their safety seats. This study, which detected harness/shield usage errors as well as installation errors, found an overall misuse rate of 65 percent. For instance, 33 percent of the infant carriers observed were facing forward rather than rearward, 22 percent of the harnesses or shields for toddler seats were not used and 62 percent of the harnesses or shields were not used for the observed booster seats.

Such modes of misuse may counteract the potential crash protection of safety seats. Sled tests, such as those conducted by Kelleher, et al. (1983) and Weber and Melvin (1983) graphically demonstrate how the improper installation of a safety seat can allow a child's head movements to exceed safe limits or even lead to the total collapse of the seat. Test dummies unsecured by harnesses or shields were flung completely out of the seat. These sled tests also document that some misuse modes are potentially more dangerous than others. Investigations of crashes have supported these test results. In-depth investigations and case history documentation of crashes involving children show that properly used safety seats provide excellent protection in crashes and that misused seats provide adequate protection in some misuse modes and crash circumstances (Melvin, et al., 1980; National Transportation Safety Board, 1983).

Partyka (1983) analyzed data from a national sample of children involved in "tow-away" crashes which was able to distinguish properly used safety seats as opposed to seats that were available but not used or used without the child being secured within the seat. Of the 70 children in the sample with an available safety seat in the car and the use of the seat was known, 5 of the children were not properly secured in the seat. Based on this small sample and broad definition of proper/improper use, properly used safety seats were found to be 83 percent effective in preventing injury of any severity as opposed to unrestrained children.

In 1983, the National Highway Traffic Safety Administration issued a subcontract through Opportunity Systems, Inc. to the University of North Carolina Highway Safety Research Center to derive a valid assessment of the injury reduction potential of safety seats and belts for children in crashes (Hall, et al., 1984). The results of this study indicated that in lower severity crashes, properly and improperly used safety seats were both 81 percent effective in preventing serious head injuries and fatalities but that in higher severity crashes, improperly used safety seats were only 29 percent effective as opposed to 74 percent for properly used seats. While these effectiveness estimates were based on a large sample of accidents and verified and supplemented police accident reports, there were some possible biases in the proper/improper classification that required additional coding of the data to correct. This process will be described in the following section.

DATA COLLECTION METHODOLOGY

The data used for this current analysis is a sample of North Carolina traffic accidents involving children less than age four from May, 1983 to March, 1984. North Carolina law requires that all traffic accidents that produce any personal injury or total property damage amounting to $200 (in 1983) be investigated by local or state police and that completed accident reports be forwarded to the North Carolina Department of Transportation, Division of Motor Vehicles (DMV). Investigating officers are required to list seating position, injury classification, restraint use, race, sex and age for all occupants. Thus, injury and restraint status is available for all children reported as being involved in an accident. Following is a brief review of the methodology used to sample the accident cases, conduct telephone interviews to verify and supplement information contained on the reports, and to edit and code the resulting information prior to analysis. A more detailed description can be found in the project report (Hall, et al., 1984).

Sampling Procedures

At the Division of Motor Vehicles, each day's batch of incoming accident reports was screened and reports on those accidents in which a child less than four was a passenger in a relevant passenger vehicle were forwarded to a DMV analyst. Since the volume of North Carolina crashes involving children <4 years old was too large (around 40 per day) to permit HSRC to interview all cases, a sampling procedure was devised. Restraint and injury cases were oversampled because of particular interest and because these categories occurred less frequently in the accident population. The analyst removed any non-reportable cases (less than $200 property damage and no personal injury or those on private property) before drawing the day's sample. The analyst then divided the day's cases into four groups:

1. Restrained Injured (RI): All crashes with at least one restrained child <4, and at least one such restrained child injured.

2. Restrained Uninjured (RU): All crashes with at least one restrained child <4, and no such restrained child injured.

3. Unrestrained Injured (UI): All crashes with one or more children <4, none restrained, and at least one such unrestrained child injured.

4. Unrestrained Uninjured (UU): All crashes with one or more children <4, none restrained, and no such unrestrained child injured.

Procedures were established to randomize case selection within groups and to replace unreachable and/or inappropriate respondents. Daily sample sizes and the number of completed interviews are shown in Table 1.

Table 1 - Daily Sample by Restraint and Injury

	DMV Daily Case Load	Daily Sample Size	# Completed Interviews	% of Total
RI	0-1	All	277	10.8
RU	10-11	4	784	37.2
UI	3-4	4	408	19.4
UU	22-25	4	686	32.6
	35-41	12-13	2105	100.0

Clearly, the requirement of a telephone interview introduces a bias encountered in any sample based on such procedures which is the likelihood that the sample reached by telephone is higher in socioeconomic indicators than the accident population as a whole. There was no option but to accept this bias, since the added information was central to this project.

Determination of Sampling Weights

The sampling procedure was designed so that differing proportions of cases in the four different restraint/injury categories were interviewed. In order to draw inferences to the entire North Carolina population of accidents involving children under 4 years of age it was, therefore, necessary to weight the sampled cases inversely to their sampling proportions prior to analyses.

Interviewing Process

Since obtaining valid, complete and useful information was crucial to the goals of this study, much effort went into the development of the interviewing protocol and instruments and in the training of the interviewers.

A priority listing of appropriate respondents was specified for the interviews. In order of priority, interviews were attempted with the (1) driver, parent of child; (2) parent of child, passenger in car; (3) driver, not parent of child; (4) parent not in car; (5) relative of child, passenger in car; (6) other passenger; (7) investigating officer; (8) someone other than above. Information on fatal accidents was obtained from the investigating officers and Medical Examiners' reports.

The analyst at DMV completed as many interviews as possible from the sample during the day. At the end of each day, the analyst forwarded the sampled and non-sampled reports to HSRC via State Courier mail. Two interviewers conducted interviews during evening hours from HSRC.

Considering the difficulties involved in contacting respondents and the nature of information being sought, the rate for completing interviews was surprisingly high. Out of 2643 cases sampled and attempted, 2105 (80%) were completed. Of the 538 cases not completed, only 99 were due to respondent refusal. The majority, 390, were incomplete due to being unable to contact the driver. The other 49 were due to language and other miscellaneous problems.

Injury Coding Scheme

One of the most difficult decisions to be made during the planning stages of this project was what type of injury information to obtain, how to obtain it, and how to convert it into a format useful for analysis. The injury scaling system used for NC accident data is the KABCO scale with very broad, general injury categories. For this scale, injuries are defined as: K = killed; A = incapacitating (preventing normal activities at least 24 hours); B = nonincapacitating (injury other than A or K evident at the scene); C = complaint of pain or momentary unconciousness; and 0 = no injury. An injury scaling system with much more precise definitions of the injuries currently being used for injury analyses is the Abbreviated Injury Scale (AIS) developed by the American Association for Automotive Medicine (1980). As stated in the instructions, the AIS depends primarily on detailed hospital and medical records for valid coding of injuries. Due to the scope of this study and a limited span of time, it was decided that obtaining medical records would be an impossible task. The only injury information available for this study was from interviews with respondents having differing degrees of familiarity with the injuries sustained by children. Thus, the decision was made to utilize an injury coding scheme other than the AIS.

After reviewing various injury coding schemes, it was decided to use, with modifications, the New York State Injury Coding Scheme (NYSICS) developed for use by police officers in New York State (Spence, 1974). A validity study has shown substantial compatibility between the NYSICS and the AIS (Spence, 1975). The NYSCIS appears to be the best combination of more detailed injury information based on reports from non-medical personnel.

In the NYSICS and for the current study, the location of the most severe physical injury is identified by one of the following codes:

1) Head (not eye or face)
2) Face (not eye)
3) Eye
4) Neck
5) Chest
6) Back
7) Shoulder - upper arm
8) Elbow - lower arm - hand
9) Hip - upper leg
10) Knee - lower leg - foot
11) Abdomen
12) Victim (over all)

The numeric values for type of physical complaint were also adapted from the NYSICS and include the following categories:

1) Amputation
2) Concussion
3) Internal injuries
4) Minor bleeding
5) Severe bleeding
6) Minor burn
7) Moderate burn
8) Severe burn
9) Fracture, dislocation
10) Contusion, bruise
11) Abrasion
12) Complaint of pain

The NYSICS includes a third injury descriptor, the victim's apparent status at the accident scene such as death, unconsciousness, shock, etc. Since the interview for the study was being conducted at least several days after the accident, it was decided to substitute an "outcome" code for a "status" code. This information, not available in reports from the scene, was easily coded from the respondent's self-reported answer to the question: "What type of treatment was required?" The following categories and definitions were used to assign a single numeric value to the outcome of injury variable:

1) No treatment, none required

2) Treated at home by self or others with home or over-the-counter remedies

3) Examined and treated by emergency room personnel after leaving the scene of the accident and released

   Examined and treated by private physician, dentist, or chiropractor after leaving the scene of the accident or within 48 hours

4) Examined by emergency room personnel and admitted to the hospital for less than 24 hours

5) Admitted to hospital for 24 hours or more

6) Permanent disability

7) Death, either at the scene of the accident or at the hospital

9) Refused to answer

Obtaining Injury Information

During the course of an interview, the respondent was asked if the driver and each of the occupants were injured. If the response was affirmative, further open-ended questions were asked to elicit information on location of injuries, the type of injuries, and their outcome. It was rare that a respondent would refuse to answer about injuries. On the whole, interviewers reported that respondents described the injuries in terms that echoed the medical diagnosis and treatment. The interviewers developed a sense of reasonable expectations of injuries based on the officer's reports of crash severity, restraint use and narration of the accident events. Major inconsistencies between the officer's assessment and that of the respondent, while rare, could be further examined in the interview.

Completed interviews with injury information on driver and occupant in narrative form were given to a research associate for coding. There was space given for coding of the two most severe (life-threatening) injuries. The decision as to the priority was solely the responsibility of the associate who was doing the coding. Her decision was based on certification and three years' service as an Emergency Medical Technician. Most respondents who reported an injury listed only one as a result of the accident. In the case of drivers this was 84%; for occupants, 92%.

Injury Scale

These injury codes, still not sufficient for purposes of analysis, have been further collapsed and combined for constructing an injury scale.

The interview data for injuries is categorized on three dimensions: location, type and outcome. The following procedure allows for scaling on those dimensions, thus giving a clearer picture of the life-threatening potential of different types of injuries. This scaling has been applied to the first injury listed since that injury is coded as the most life-threatening.

For scaling, each injury location, type and outcome is given a numerical score (Table 2), and then the scores are added to determine seriousness. Possible scores were 0-21 were 0 equals no injury and a higher score is more serious. For instance, a fractured arm requiring treatment in the emergency room would score (1 + 7 + 5) = 13. Fatalities are automatically assigned a score of 21 regardless of injury location or outcome.

In order to conveniently and validly use the Injury Score values, the possible range of values was collapsed into five categories. This was done by reviewing a frequency distribution of Injury Scores indicating all possible combinations of injury location, type and outcome values used to compute the scores. Ranges of scores were then grouped together to make up five categories

Table 2 - Injury Combinations for Injury Score Construction

Location Score	Type Injury Score	Outcome Score
Extremities = 1	None visible, complaint of pain, abrasion = 1	No treatment or home treatment = 1
Torso = 2	Contusion, bruise = 3	Checked at ER, by MD, dentist or chiropractor = 3
Head, face, eye, neck = 3	Minor burn (1°), minor bleeding, whiplash = 5	Admitted to hospital less than 24 hours = 4
	Internal injury, fracture/dislocation = 7	Admitted to hospital more than 24 hours = 5
	Concussion, moderate burn (2°), severe bleeding (anything requiring stitches = 9	Permanent disability = 6
	Amputation, severe burn (3°) = 10	Death = 7

that represent logical breaks among different types of injuries. The categories thus derived, in order of decreasing severity, are as follows:

Severe Head Injuries, Fatalities (Injury Score Values = 15-21): Severe head injuries, those defined as concussion, fractures or severe bleeding and generally requiring hospitalization were grouped with the fatalities.

Severe bleeding or fractures other than head (Injury Score Values = 11-14): This range of scores consists primarily of injuries to regions other than the head that result in severe bleeding (requiring stitches) or fractures or dislocation.

Minor bleeding or whiplash (Injury Score Values = 9-10): This category includes all other visible injuries with minor cuts (not requiring stitches) to any part of the body being the most prevalent injury. Injuries described as "whiplash" were included in this category since pain and discomfort from whiplash can be quite incapacitating.

Bruises, pain (Injury Score Values = 3-8): Victims who were reported as injured but who had no visible injuries are included in this category.

No Injury (Injury Score Value = 0): No injury reported.

It is acknowledged that this injury scale is not as sophisticated as other scales such as the Abbreviated Injury Scale, but it was determined that the type and quality of data that could be elicited from the respondents greatly limited the type of scale that could be constructed.

Restraint Coding

In addition to obtaining injury information that was as accurate and detailed as possible, it was imperative that the same amount of care be taken in obtaining valid information regarding restraint use. This is one reason that interviews were conducted, when possible, with a child's parent who was the driver or occupant of the accident involved vehicle. It was felt that the parents could provide the most complete information on restraint use by these children.

If the respondents indicated that the child was secured in a safety belt, the questioning ended at that point. If the child was reported to be in a safety seat or booster seat, further information was elicited from the respondent to determine both the type of restraint and the manner in which it was used.

First, the respondent was asked to give the brand name and model number of the safety seat and where they obtained it. For those who did not know this information, a separate mail survey form was sent to them to fill out and return. Next the respondent was asked if the child was buckled into the safety seat at the time of the accident and if so, to describe how. Respondents were then asked if the child and the seat were facing to the front or the rear of the car, if the seat was buckled into the car and, if so, how it was secured. For those who were reported to be using forward facing seats, they were asked whether or not the seat required a top tether strap and if and how it was being used if required. Finally, the respondent was asked if the child stayed in the safety seat and if the seat remained in place during the accident and if not, where they ended up.

At the time of the original analysis, information was not available due to low and slow response rates to the mail back surveys. Thus, the definition of proper and improper usage was based on information that was available from the interview itself and very few respondents indicated during the interview what model of seat was being used. If the respondent stated that the child was in a safety seat, that the child was buckled into the seat, that it was appropriately positioned front or rear facing based on the child's weight, that the seat was secured to the car, that the child stayed in the seat during the crash and that the seat stayed in place, the seat was coded as being correctly used. Using this rather crude definition of proper/improper usage based at least partially on outcome, 65 percent of the 2635 (weighted) seats in use in these accidents were properly used. This proper use rate is the reverse of the results found in surveys where two-thirds of the observed seats were found to be misused (Cynecki and Goryl, 1984; Shelness and Jewett, 1983). A proper/improper usage classification based on the model of seat and determination of how it was installed and used should provide a more valid assessment of the performance of safety seats in crashes and how different misuse modes can reduce the effectiveness of those seats.

Supplemental Data Collection

Safety seat proper/improper usage classification.

In order to conduct a more valid assessment of the effects of misuse on the effectiveness of safety seats, it was necessary to review and recode the existing data. For this purpose, a listing was generated of all safety seats involved in accidents contained on the original data file. The list contained the case identification number, occupant identification number, age, and weight for all cases where a safety seat was in use. Also listed for each case were the seat brand name and model number provided through both the original interview and the follow-up mailback survey. Using the case and occupant identification numbers, the appropriate original interview forms were pulled for review.

At this point, the author reviewed and assigned three codes to each case:

1) Brand name -- Based on the name provided through the interview and the mailback survey. If there was a discrepancy between names provided during the interview and on the mailback survey, the brand name and model number provided on the mailback was assumed to be more accurate and used for remaining coding.

2) Type of seat used -- Each seat was assigned a code to specify what type of seat was in use. Convertible seats were classified according to their proper mode based on the weight of the child. For instance, a convertible seat being used for a 15 pound infant would be classified as a "convertible seat, infant mode" regardless of the front/rear orientation of the seat. Seat types were also classified according to the type of harness or shield system used for that particular model.

3) Proper/improper seat usage -- Using the seat name and other available information, a determination was made as to whether or not the seat was being used correctly according to the manufacturer's instructions. This decision was based on the front/rear orientation of the seat (with seat type and weight of child used to determine proper orientation), if the harness or shield was being used, how it was being used, if the seat was secured with the seat belt, how it was routed through or around the seat, and if and how the tether was secured for those seats requiring a tether strap. Seats were assigned to a specific proper use code only if the descriptions of harness use and seat securement were detailed and clear enough to make a judgment. Seats were assigned to the "unable to determine" category when there was reasonable doubt regarding proper/improper usage. It should be noted that in the original proper/improper usage classification, whether or not the child and the seat stayed in place during the accident were used to classify proper usage. This information was not, however, used in the reclassification of proper/improper usage. In fact, all efforts were made not to look at the outcome information, as well as injury status, to ensure that the classification was made independent of outcome.

Once these additional codes were assigned to each case, this information was entered on a computer file and merged with the appropriate cases on the original file for analysis.

Even though this process was able to produce a more detailed and valid misuse assessment, several limitations should be kept in mind. These judgments were based on a description of harness use and seat securement provided by the respondents. The respondents may not have been totally accurate in their recollection of how the seat was being used. Even when accurate in their recollections, it is difficult to describe how a seat is installed or a harness is being used and this description was written down by the interviewer. Hence, a large number of "unable to determine" assignments resulted from this procedure.

Distance from home information.

Another aspect of this project was to attempt to determine the distance from home that children were when the accident occurred. Most of the information needed for this determination was already available through the accident report form and the interview form. Since it was necessary to physically measure this distance on maps and since the basic information desired from these measurements was the proportion of children involved in accidents within various distances from home, this information was collected for a sample of the original interview sample.

First, an approximate 10 percent sample of the 2105 completed interviews was selected based on case identification numbers. The original accident reports and interview forms were pulled for the 200 selected cases. In those cases where there were more than one child in the case vehicle, appropriate forms were pulled for all children less than four years of age. The accident report form provides a specific accident location and lists the address for all drivers. The investigating officer is also required to report the addresses for all injured occupants, including children. Thus, accident location and the child's address were readily available for all injured children. For uninjured children, the interview form was used to determine the relationship of the child to the driver. If the driver was the parent of the involved child, then it was assumed that they shared the same address and the driver's address was used for measurements. No addresses could be determined for children in cases where the child was uninjured and not the driver's child. In these cases, the driver's address was used for measurements and it was noted that it was the driver's address for later analyses.

The cases where the address given for the child was a street address presented very few problems. Many of the addresses, however, were rural route mailing addresses. Since these cannot be located on a map, it was necessary to call the post office for the city or town listed. In most cases, the carrier for the appropriate route was able to provide a location that could then be found on the maps.

The accident location information, the child's address, the driver's address and how the child's address was derived were then transferred to a separate form. These forms were then taken to the N.C. Department of Transportation, Division of Motor Vehicles Traffic Engineering Branch where maps are available for all counties and cities in North Carolina. Using these maps, the accident location was pinpointed using information provided by the investigating officer. Then the child's address was located as precisely as possible. Once these two locations were determined, the straight line distance between the two points were measured and converted to miles using the map's mileage scale. Next, a string was laid down along the most probable route between the two points, straightened out and again converted to miles using the scale. This "probable route" measure yielded an approximate measure of the distance that would actually be driven between the two locations along the most direct route between the two points. Of course, it is impossible to say that this was the route that had actually been driven, or would have been driven if going home, but it does give a measure of actual driving distance between the two points. The same procedure was followed for the driver's address if different from that of the child.

As with all samples, one must be concerned with the representativeness of the sample. This was especially of concern for the distance from home measurement since this is based on a subsample of the original sample. Since very simple information was being requested of the data, it was decided that a subsample of 100 cases would be sufficient for valid results. Two hundred cases were selected in order to be certain to end up with one-hundred complete cases. Of the 200 selected cases, 33 did not have an address for the child that could possibly be located on a map and efforts to obtain such an address through the post office were unsuccessful. (For 27 of the remaining 167 cases, either the child's address or the accident location could not be found on the map.) Locations were found on the maps for 140 cases and the measurements were completed. Thus, the final data set used for the distance from home calculations is based on 140 cases, well above the target of 100 cases. In addition, several of the 140 completed cases had more than one child in the car. There were a total of 179 children less than four in the final set of completed measurements. This subsample was compared to the total sample of 2105 telephone interviews to determine how representative it is. As was mentioned, the original cases were assigned weights to make them representative of the population of accident involved children in North Carolina. As shown by Tables

Table 3. Time of Day Accident Occurred.
Subsample vs. Total Sample

Time of Day	Weighted Subsample %	Weighted Total Sample %	Statewide %
12:00 - 3:59 a.m.	0.3	0.7	1.5
4:00 - 7:59 a.m.	2.7	6.3	5.0
8:00 - 11:59 a.m.	19.0	20.0	19.2
12:00 - 3:59 p.m.	34.3	30.6	30.5
4:00 - 7:59 p.m.	35.5	34.0	33.6
8:00 - 12:00 p.m.	8.3	8.5	10.2
	100.0	100.0	100.0

Table 4. Day of Week Accident Occurred.
Subsample vs. Total Sample

Weekday	Weighted Subsample %	Weighted Total Sample %	Statewide %
Monday	15.6	14.4	13.5
Tuesday	15.3	13.6	13.1
Wednesday	12.5	13.1	12.4
Thursday	12.6	13.4	12.6
Friday	17.3	19.8	21.3
Saturday	15.3	14.6	15.2
Sunday	11.4	10.9	11.9
	100.0	100.0	100.0

Table 5. Road Class on Which Accident Occurred.
Subsample vs. Total Sample

Road Class	Weighted Subsample %	Weighted Total Sample %	Statewide %
Interstate	5.6	2.5	2.9
US Route	22.3	20.6	21.7
NC Route	17.2	17.3	16.3
Secondary	18.0	21.5	21.6
Local Street	36.3	37.2	36.7
Other Public	0.7	0.5	0.3
	100.0	100.0	100.0

3 through 6, the subsample is very similar to the total sample and to the population of statewide accidents in several characteristics.

Table 6. Locality in Which Accident Occurred.
Subsample vs. Total Sample

Locality	Weighted Subsample %	Weighted Total Sample %	Statewide %
Rural (<30% Developed)	28.5	29.1	29.9
Mixed (30% - 70% Dev.)	20.8	21.2	21.0
Urban (>70% Developed)	50.7	49.8	50.2
	100.0	100.0	100.0

Thus, it appears that the subsample selected for the distance from home measurements is very similar to and representative of the original sample and the population of accident involved children in North Carolina.

RESULTS

Distance From Home

Four basic measures are available to determine how far children were from their home when their accident occurred. As was previously mentioned, two distances were measured for each accident. One was a straight line measure from the accident location to the child's address and the other was a measure of the distance along the most probable route between the two points. These measurements were taken for all children less than four in the vehicle. The proportion of children involved in accidents within a certain distance is the result when the data is analyzed for all children. If only one child per vehicle was included for analysis while additional children are excluded, the resulting data will indicate the proportion of accidents with children involved that occur within a certain distance of home. Table 7 gives the results for these four different measures.

Table 7. Distance From Home to Where Accident Occurred. Weighted Sample.

Straight Line Measure (Miles)	Children Involved %	Children Involved (N)	Vehicles Involved %	Vehicles Involved (N)
< 1.0	16.4	(96)	17.2	(79)
1 - 4.9	36.1	(211)	37.0	(170)
5 - 9.9	18.7	(109)	17.4	(80)
10 - 14.9	10.6	(62)	9.1	(42)
15 - 19.9	4.1	(24)	4.7	(22)
20 - 29.9	5.7	(33)	5.5	(26)
30 - 49.9	0.8	(5)	1.0	(5)
50 - 99.9	2.4	(14)	3.0	(14)
100+	5.1	(30)	5.1	(23)
Total	100.0	584	100.0	461

Probable Route Measure (Miles)	Children Involved %	Children Involved (N)	Vehicles Involved %	Vehicles Involved (N)
< 1.0	13.8	(80)	13.7	(63)
1 - 4.9	32.8	(191)	32.7	(150)
5 - 9.9	21.6	(126)	21.1	(97)
10 - 14.9	7.7	(45)	6.0	(28)
15 - 19.9	4.6	(27)	5.3	(24)
20 - 29.9	8.8	(52)	9.7	(44)
30 - 49.9	2.7	(16)	2.5	(12)
50 - 99.9	2.9	(17)	3.7	(17)
100+	5.1	(30)	5.1	(23)
Total	100.0	584	100.0	458

As can be seen in Table 7, there are only small differences between the occupant orientation (Children Involved) and the vehicle orientation (Vehicles Involved) for both the straight line and the probable route measure for any given distance category. Larger differences do occur between the distance categories when comparing the straight line measure against the probable route measure.

A review of Table 7 clearly shows the need to protect children in cars even on very short trips. Sixteen percent of the children were involved in accidents less than one mile from their home when measured on the straight line. This proportion was slightly smaller, almost 14 percent, when measured along the probable route. Even along the probable route, one-third of the children were involved in their accidents somewhere between 1 and 4.9 miles from their home. When the first three distance categories are combined, it can be seen that 7 out of 10 children (71.2%) were involved in accidents less than ten miles from home when measured on the straight line. This proportion dropped slightly to 68.2 percent when the probable route measure was used.

Also of interest is whether or not the distance from home when an accident occurred had any discernable relation to restraint usage. Table 8 shows restraint usage while controlling for distance from home. The distance

Table 8. Restraint Usage by Distance From Home. All Children, Probable Route.

Distance From Home (Miles)	Restraint None Row %/(N)	Seat Belt Row %/(N)	Safety Seat Row %/(N)	Total Col %/(N)
< 5	64.4 (167)	8.2 (21)	27.5 (71)	45.9 (259)
5-9.9	32.7 (41)	19.4 (24)	47.9 (60)	22.2 (125)
10-19.9	43.5 (28)	25.4 (16)	31.1 (20)	11.4 (64)
20-49.9	59.4 (40)	12.7 (9)	27.9 (19)	12.1 (68)
50+	22.3 (11)	4.1 (2)	73.6 (35)	8.5 (48)
Total	50.9 (287)	12.8 (72)	36.4 (205)	100.0 564

categories have been collapsed into five categories in order to insure larger numbers in each cell. The data presented is for all children using the probable route measure.

Overall, 50.9 percent of the children in this sample were unrestrained at the time of the accident. Unrestrained children are overrepresented to a considerable degree among the accidents that occurred within 5 miles of their home. In contrast, children involved in accidents more than 50 miles from their home were much less likely to be unrestrained. These results are consistent with the feeling expressed by some that accidents occur on long highway trips and thus restraints are not needed on short trips around town. It does appear that drivers are more likely to buckle up children on long trips (77.7%) than on short trips (35.7% for accidents < 5 miles from home). Overall, it appears that children are most likely to be unrestrained when they are within five miles of home. Within more moderate distances from home, children are more likely to be restrained, but that restraint is more likely to be a safety belt rather than a safety seat and the safety seats are being used for the longest trips.

In order to test the significance of these results, a X^2 test was applied to the proportions of children restrained and unrestrained who were involved in accidents within five miles of home and for those five miles or greater from home. Whereas children who were in accidents less than five miles from home were unrestrained 64.4 percent of the time, children in accidents five miles or greater from home were unrestrained 39.3 percent of the time. This test was found to be statistically significant ($X^2 = 10.97$, $p < 0.05$) after adjustment for sample inflation.

Caution should be urged when interpreting this data, however, since the only thing known is how far from home the accident occurred. What is not known is the length of the planned trip upon leaving home. It is entirely possible and probable that a substantial number of the accidents occurring close to home were actually trips that were planned for longer distances. It would be interesting to determine restraint usage rates for children and adults when they embark on a planned short trip versus a long trip. Also of interest is how close to their destination children are and their restraint status.

Table 9 presents distances from home in relation to crash severity. Crash severity has been measured as the investigating officers' assessments of a TAD rating which is damage to the vehicle as defined by the Vehicle Damage Scale for Traffic Accident Investigators (National Safety Council, 1971). Overall, 25 percent of the children were involved in high severity accidents (TAD 4-7) with

Table 9. Distance from home by crash severity, all children, probable route.

Distance from Home (Miles)	TAD 1-3 N/Row %/Col %	TAD 4-7 N/Row %/Col %	Total N/Col %
< 5	188	69	257
	73.2	26.9	48.3
	47.1	51.9	
5-9.9	95	20	115
	82.6	17.4	21.6
	23.8	15.0	
10-19.9	46	15	61
	75.4	24.6	11.5
	11.5	11.3	
20-49.9	35	21	56
	62.5	37.5	10.5
	8.8	15.8	
50+	35	8	43
	81.4	18.6	8.1
	8.8	6.0	
Total	399	133	532
	75.0	25.0	

the other children in lower severity accidents. Perhaps the most important aspect of this distribution is that 27 percent of the accidents occurring within five miles of home were of high severity, slightly higher than for the high severity proportion of all accidents. Conversely, those accidents occurring at a distance of greater than 50 miles were underrepresented among the high severity crashes. For all accidents five miles or greater from home, 17 percent were of high severity as compared to the 27 percent for less than five miles. Thus, it can be said that being involved in an accident close to home is no guarantee of it being a minor one.

Table 10 presents the distribution of injuries while controlling for distance from home. In order to produce truly meaningful results in regard to injury level, it would be necessary to also control for crash severity and restraint usage. Unfortunately, the sample size is too small to control for these two variables as well as injury level. It can be said, however, that the potential for receiving injuries exists even within a few miles of home. As with Table 10, injuries resulting from these accidents were tested for

Table 10. Injury level by distance from home.
All children, probable route.

Distance From Home (Miles)	No Injury Row %/(N)	Bruises, Pain Row %/(N)	Minor Bleeding Row %/(N)	Stitches, Fracture Row %/(N)	Severe Head, Fatal Row %/(N)	Total Col %/(N)
< 5	86.6 (234)	4.4 (12)	5.2 (14)	2.6 (7)	1.1 (3)	47.3 (270)
5-9.9	89.8 (108)	0.0 (0)	6.0 (7)	2.6 (3)	1.6 (2)	21.0 (120)
10-19.9	79.9 (54)	8.9 (6)	4.7 (3)	1.8 (1)	4.7 (3)	11.7 (67)
20-49.9	84.7 (57)	1.8 (1)	7.6 (5)	0.0 (0)	5.9 (4)	11.7 (67)
50+	93.3 (44)	0.0 (0)	4.1 (2)	2.6 (1)	0.0 (0)	8.2 (47)
Total	86.8 (497)	3.4 (19)	5.4 (31)	2.1 (12)	2.1 (12)	100.0 (571)

significance after further collapsing distance and injury data. Children in accidents less than five miles from home received injuries 13.3 percent of the time whereas 12.6 percent of the children in accidents five miles or greater from home received any injury. This difference is not statistically significant (adjusted $X^2 = .104$, $p > .75$) indicating that children close to home are as likely to be injured as are children further from home.

In summary, this sample indicates that nearly half of all accident involved children are involved in these accidents within five miles of home and two-thirds are involved within ten miles of home.

These accidents occurring close to home are as likely to be severe accidents as are accidents occurring farther from home. The fact that nearly two-thirds of the children involved in accidents within five miles of home were unrestrained at the time of the accident (a higher level of non-restraint than for any other distance) indicates that there is a pressing need to continue to encourage parents to buckle up their children even on short trips around town.

Injury Producing Mechanisms Associated with Correct and Incorrect Use of Different Types of Seats

As was previously mentioned, there is widespread concern over the extent of observed misuse of safety seats and the subsequent potential for reducing the effectiveness of the seats. In order to address this relationship, the safety seats being used were classified as to whether or not they were being used correctly and if not, the type of misuse. For this analysis, the type of use/misuse has been placed in one of four categories:

Proper Use: The seat in question was being used according to the manufacturer's instructions.

Gross Misuse: Either the seat was not secured by the vehicle seat belt, the child was not secured by the harness or shield or neither the seat belt nor the harness or shield were being used.

Partial Misuse: Both the seat belt was being used to secure the seat and the harness or shield was being used, but one or the other was routed or used incorrectly or there was some other type of misuse, such as front/rear facing error or tether nonuse or misuse evident.

Unable to Determine: In many cases, it was not possible to determine how the seat was being used.

To say the least, it was extremely difficult to make confident determinations of proper and improper usage. It is difficult for people to describe how a seat has been used with enough clarity for someone else to understand. In addition to this, the proper/improper usage determination were made according to what the interviewer had listed on the form and these notes in themselves were sometimes hard to understand. Thus, it is not surprising that in a third (31%) of the cases it was not possible to make a proper/improper usage determination. Table 11 shows the different types of seats and the proportions of proper/improper classification for each. For these analyses, seat types have been categorized as follows:

IC = Infant carrier, those seats designed for use only by infants in the rear facing position (e.g., Infant Love Seat, Dyn-O-Mite).

CI = Any type of convertible seat used for infants weighing less than eighteen pounds.

C5 = Convertible seats with a full 5-point harness system when used for a toddler eighteen pounds or over (e.g., Astroseat, Safe & Easy).

CH+S = Convertible seat with a harness plus a separate shield when used for a toddler (primarily Bobby Macs).

CH/S = Convertible seat with a harness shield combination where the harness is attached to the shield (e.g., Century 200, One-Step).

CT = Any convertible seat used in the toddler mode and that requires a tether (primarily Strolee Wee Cares).

TOD = Any seat designed for use only by toddlers over 18 pounds (e.g., Child Love Seat, Tot Guard).

BH = Booster seat with harness (e.g., Safe-T-Rider, Tot-Rider).

BS = Booster seat with shield (primarily Collier Keyworth Co-Pilot).

NC = Non-crash tested models.

UNK = Unknown type.

For the non-crash tested models and the unknown seats, proper/improper usage classifications were not possible except when the description indicated non-use of the harness and/or the seat belt.

A quick glance at Table 11 shows that there is a great deal of missing information. Almost one-third (31%) of the seats in use were classified as "Unknown" type or model. That is, the respondents did not identify the seat adequately enough to determine the model and thus the type. Furthermore, of those 1847 crash-tested seats that were identifiable, another 10 percent (185) were classified as unknown usage due to inadequate descriptions of how the seats were used.

Looking down the column for the "Unknown" usage classification, there were large differences between types of seats and the ease with which they could be classified. Of all of the types, the harness type booster (BH) was easiest to judge, primarily because they were most often obviously grossly or partially misused. The convertible seat with harness plus shield (CH+S) was also easy to judge. This category is made up of almost entirely of Bobby Macs and their proper use as well as misuse is easy to describe and understand. The same is true for the tethered convertibles (CT) which were primarily Strolees. Since the tethers were infrequently used, the proper/improper classification was made easier.

On the other hand, it was fairly difficult for the respondents to describe the non-tethered convertible in a manner in which a confident determination of

Table 11. Proper/Improper Usage Classifications by Seat Type Weighted.

	Proper/Improper Usage Classification				
Seat Type	Proper Row %/(N)	Gross Misuse Row %/(N)	Partial Misuse Row %/(N)	Unknown Row %/(N)	Total Col %/(N)
IC	37.9 (120)	19.7 (62)	34.3 (108)	8.2 (26)	11.5 (316)
CI	30.1 (66)	4.1 (9)	49.3 (108)	16.4 (36)	8.0 (219)
C5	31.6 (79)	7.6 (19)	43.2 (108)	17.6 (44)	9.1 (250)
CH+S	24.0 (58)	7.9 (19)	65.7 (159)	2.5 (6)	8.8 (242)
CH/S	45.9 (101)	2.1 (5)	28.8 (63)	23.2 (51)	8.0 (220)
CT	5.7 (24)	5.2 (22)	83.3 (350)	5.7 (24)	15.3 (420)
TOD	44.7 (21)	0.0 (0)	51.1 (24)	4.3 (2)	1.7 (47)
BH	17.9 (14)	7.7 (6)	73.1 (57)	1.3 (1)	2.8 (78)
BS	46.3 (26)	3.8 (2)	38.2 (21)	11.7 (6)	2.0 (55)
NC	-- --	68.5 (30)	-- --	31.5 (14)	1.6 (44)
UNK	-- --	10.6 (90)	-- --	89.4 (759)	31.0 (849)
TOTAL	18.6 (509)	9.6 (264)	36.4 (998)	35.4 (969)	100.0 (2740)

IC = Infant carrier
CI = Convertible seat, used by infant (<17lbs.)
C5 = Convertible seat, 5-point harness, used by toddler
CH+S = Convertible seat, harness plus separateshield
CH/S = Convertible seat, harness/shield combination
TOD = Toddler only seat
CT = Convertible seat, tethered
BH = Booster seat, harness type
BS = Booster seat, shield type
NC = Non crash-tested
UNK = Unknown

Table 12. Proper/Improper Usage Classifications by Seat Type Weighted. Unknown Excluded

Seat Type	Proper Row %/(N)	Gross Misuse Row %/(N)	Partial Misuse Row %/(N)	Total Col %/(N)
IC	41.2 (120)	21.4 (62)	37.4 (108)	17.6 (290)
CI	36.2 (66)	4.7 (9)	59.2 (108)	11.1 (183)
C5	38.2 (79)	9.3 (19)	52.5 (108)	12.5 (206)
CH+S	24.5 (58)	8.0 (19)	67.5 (159)	14.3 (236)
CH/S	59.8 (101)	2.7 (5)	37.5 (63)	10.2 (169)
CT	6.0 (24)	5.5 (22)	88.5 (350)	24.0 (396)
TOD	46.7 (21)	0.0 (0)	53.3 (24)	2.7 (45)
BH	18.2 (14)	7.9 (6)	74.0 (57)	4.7 (77)
BS	52.5 (26)	4.3 (2)	43.3 (21)	3.0 (49)
TOTAL	30.8 (509)	8.7 (144)	60.5 (998)	100.0 (1651)

IC = Infant carrier
CI = Convertible seat, used by infant (<17lbs.)
C5 = Convertible seat, 5-point harness, used by toddler
CH+S = Convertible seat, harness plus separateshield
CH/S = Convertible seat, harness/shield combination
CT = Convertible seat, tethered
TOD = Toddler only seat
BH = Booster seat, harness type
BS = Booster seat, shield type

usage could be made and thus, relatively large numbers had to be classified as unknowns. Since there is no reason to believe that either properly or improperly used seats would be more likely to be classified as unknown usage, it should be valid to review the same table with unknowns excluded.

When Table 12 is examined, it is readily apparent that there are large differences between types of seats and their level of misuse. For infants, the infant carriers were more likely to be used correctly and less likely to be misused than were the convertible seats used for infants, but they were much more likely to be used without the harness or the vehicle seat belt. Perhaps this is because the convertible seats, not being as portable, are more likely to be left secured in the car when not in use. For toddlers, the highest level of proper use was for the harness/shield combination and the highest level of misuse was for tethered models. Models with harnesses plus separate shields were also partially misused often with non-use of the shield in addition to the harness the most prevalent misuse mode. Among the booster seats, the models that use a shield for upper body support were almost three times more likely to be used properly than were the harness models. Almost three-quarters of the harness type booster were used without the harness.

As discussed, there are wide variations in the levels of misuse among the different types of safety seats. Whether or not this translates into decreased crash performance is of utmost interest. Table 13 shows the injury experience of those children involved in crashes while in safety seats. For purposes of this table, injury level has been collapsed into the three categories of None/Slight (no injury, bruises, or pain), Moderate (minor bleeding, cuts requiring stitches, fractures, etc.) and Severe Head and Fatal injuries. Crash severity has been defined based on vehicle deformation based on the seven-point TAD scale. Table 13 presents data for different types of safety seats as well as for all types combined. In the "All Types" summary; non-crash tested and seats of unknown types have been excluded. For both types of seats, it was not possible to determine the type of usage and thus have not been compared to crash tested seats where type of usage is known. Unfortunately, the large amount of missing data thus excluded from this comparison limits the analysis. Nineteen severe head/fatal injuries occurred to children in some type of seat. Of these, one was to a child in a non-crash tested seat and nine were to children in seats of unknown type. Thus, over half of the severe head/fatal injuries have been

Table 13. Injury Level for Different Types of Safety Seats Controlling for Proper/Improper Usage and Crash Severity.

				Injury Level	
Seat Type	TAD Severity	Type Use Misuse	None/Slight (N) Row %	Moderate (N) Row %	Severe Head/Fatal (N) Row %
All Types*	All**	Proper	(455) 95.6	(17) 3.6	(4) 0.8
		Gross	(121) 92.4	(8) 6.1	(2) 1.5
		Partial	(839) 92.2	(69) 7.6	(2) 0.2
		Unknown	(177) 93.1	(12) 6.3	(1) 0.5
	1-3	Proper	(342) 97.4	(9) 2.6	-- --
		Gross	(92) 93.9	(6) 6.1	-- --
		Partial	(656) 95.1	(33) 4.8	(1) 0.1
		Unknown	(104) 92.0	(9) 8.0	-- --
	4-7	Proper	(73) 88.0	(7) 8.4	(3) 3.6
		Gross	(33) 89.2	(2) 5.4	(2) 5.4
		Partial	(160) 84.2	(29) 15.2	(1) 0.5
		Unknown	(41) 95.3	(2) 4.7	-- --
Infant Only	All	Proper	(109) 98.2	(2) 1.8	-- --
		Gross	(56) 98.3	(1) 1.8	-- --
		Partial	(92) 92.0	(8) 8.0	-- --
		Unknown	(23) 95.8	(1) 4.8	-- --
	1-3	Proper	(76)100.0	-- --	-- --
		Gross	(45) 97.8	(1) 2.2	-- --
		Partial	(70) 95.9	(3) 4.1	-- --
		Unknown	(10) 90.9	(1) 9.1	-- --
	4-7	Proper	(25) 92.6	(2) 7.4	-- --
		Gross	(11)100.0	-- --	-- --
		Partial	(16) 76.2	(5) 23.8	-- --
		Unknown	(10)100.0	-- --	-- --

(Continued)

*"Non-Crash Tested" and "Unknown" Seat Types excluded.
**TAD "1-3" plus "4-7" may not total "All" TADs due to missing severity ratings.

Table 13. Continued.

Seat Type	TAD Severity	Type/ Use Misuse	None/Slight (N) Row %	Moderate (N) Row %	Severe Head/Fatal (N) Row %
Convertible Infant Mode	1-7	Proper	(60) 98.4	(1) 1.9	-- --
		Gross	(3) 37.5	(3) 37.5	(2) 25.0
		Partial	(93) 93.9	(6) 6.3	-- --
		Unknown	(33) 100.0	-- --	-- --
	1-3	Proper	(42) 97.7	(1) 2.3	-- --
		Gross	-- --	(2) 100.0	-- --
		Partial	(79) 92.9	(6) 7.1	-- --
		Unknown	(19) 100.0	-- --	-- --
	4-7	Proper	(8) 100.0	-- --	-- --
		Gross	(3) 50.0	(1) 16.7	(2) 33.3
		Partial	(11) 100.0	-- --	-- --
		Unknown	(11) 100.0	-- --	-- --
Convertible Toddler Mode 5-Point Harness	1-7	Proper	(67) 91.8	(3) 4.1	(3) 4.1
		Gross	(16) 94.1	(1) 5.9	-- --
		Partial	(83) 90.2	(8) 8.7	(1) 1.1
		Unknown	(29) 87.9	(3) 9.4	(1) 3.0
	1-3	Proper	(50) 96.2	(2) 3.9	-- --
		Gross	(9) 100.0	-- --	-- --
		Partial	(66) 91.7	(5) 6.9	(1) 1.4
		Unknown	(22) 91.7	(2) 8.3	-- --
	4-7	Proper	(3) 50.0	(1) 16.7	(2) 33.3
		Gross	(7) 87.5	(1) 12.5	-- --
		Partial	(17) 85.0	(3) 15.0	-- --
		Unknown	(7) 87.5	(1) 12.5	-- --
Convertible Toddler Mode Harness Plus Shield	1-7	Proper	(50) 94.3	(2) 3.8	(1) 1.9
		Gross	(17) 100.0	-- --	-- --
		Partial	(125) 89.3	(15) 10.7	-- --
		Unknown	(4) 100.0	-- --	-- --
	1-3	Proper	(39) 97.5	(1) 2.5	-- --
		Gross	(10) 100.0	-- --	-- --
		Partial	(101) 93.5	(7) 6.5	-- --
		Unknown	(3) 100.0	-- --	-- --
	4-7	Proper	(5) 71.4	(1) 14.3	(1) 14.3
		Gross	(7) 100.0	-- --	-- --
		Partial	(20) 74.1	(7) 25.9	-- --
		Unknown	(1) 100.0	-- --	-- --

(Continued)

Table 13. Continued.

Seat Type	TAD Severity	Type/ Use Misuse	Injury Level					
			None/Slight (N)	Row %	Moderate (N)	Row %	Severe Head/Fatal (N)	Row %
Convertible Toddler Mode Harness/ Shield Combination	1-7	Proper	(87)	92.6	(7)	7.4	--	--
		Gross	(3)	75.0	(1)	25.0	--	--
		Partial	(57)	98.3	(1)	1.7	--	--
		Unknown	(38)	88.4	(5)	11.6	--	--
	1-3	Proper	(66)	93.0	(5)	7.0	--	--
		Gross	(3)	75.0	(1)	25.0	--	--
		Partial	(45)	97.8	(1)	2.2	--	--
		Unknown	(29)	87.9	(4)	12.1	--	--
	4-7	Proper	(15)	93.8	(1)	6.3	--	--
		Gross	--	--	--	--	--	--
		Partial	(6)	100.0	--	--	--	--
		Unknown	(3)	75.0	(1)	25.0	--	--
Convertible Toddler Mode Tether Required	1-7	Proper	(22)	100.0	--	--	--	--
		Gross	(20)	100.0	--	--	--	--
		Partial	(291)	90.9	(28)	8.8	(1)	0.3
		Unknown	(21)	95.5	(1)	4.6	--	--
	1-3	Proper	(20)	100.0	--	--	--	--
		Gross	(19)	100.0	--	--	--	--
		Partial	(226)	95.8	(10)	4.2	--	--
		Unknown	(16)	94.1	(1)	5.9	--	--
	4-7	Proper	(2)	100.0	--	--	--	--
		Gross	(1)	100.0	--	--	--	--
		Partial	(39)	73.6	(13)	24.5	(1)	1.9
		Unknown	(5)	100.0	--	--	--	--
Toddler Only	1-7	Proper	(19)	100.0	--	--	--	--
		Gross	--	--	--	--	--	--
		Partial	(22)	100.0	--	--	--	--
		Unknown	(2)	100.0	--	--	--	--
	1-3	Proper	(19)	100.0	--	--	--	--
		Gross	--	--	--	--	--	--
		Partial	(15)	100.0	--	--	--	--
		Unknown	--	--	--	--	--	--
	4-7	Proper	--	--	--	--	--	--
		Gross	--	--	--	--	--	--
		Partial	(7)	100.0	--	--	--	--
		Unknown	(2)	100.0	--	--	--	--

(Continued)

Table 13. Continued.

				Injury Level	
Seat Type	TAD Severity	Type/ Use Misuse	None/Slight (N) Row %	Moderate (N) Row %	Severe Head/Fatal (N) Row %
Booster Seat Shield	1-7	Proper	(24) 100.0	-- --	-- --
		Gross	-- --	(2) 100.0	-- --
		Partial	(18) 94.7	(1) 5.3	-- --
		Unknown	(5) 83.3	(1) 16.7	-- --
	1-3	Proper	(22) 100.0	-- --	-- --
		Gross	-- --	(2) 100.0	-- --
		Partial	(11) 91.7	(1) 8.3	-- --
		Unknown	(5) 83.3	(1) 16.7	-- --
	4-7	Proper	(2) 100.0	-- --	-- --
		Gross	-- --	-- --	-- --
		Partial	(7) 100.0	-- --	-- --
		Unknown	-- --	-- --	-- --
Booster Seat Harness	1-7	Proper	(1) 84.6	(2) 15.4	-- --
		Gross	(6) 100.0	-- --	-- --
		Partial	(50) 98.0	(2) 2.0	-- --
		Unknown	-- --	(1)	-- --
	1-3	Proper	(8) 100.0	-- --	-- --
		Gross	(6) 100.0	-- --	-- --
		Partial	(43) 100.0	-- --	-- --
		Unknown	-- --	-- --	-- --
	4-7	Proper	(3) 60.0	(2) 40.0	-- --
		Gross	-- --	-- --	-- --
		Partial	(7) 87.5	(1) 12.5	-- --
		Unknown	-- --	-- --	-- --
Non-Crash Tested	1-7	Gross	(15) 68.2	(7) 31.8	-- --
		Unknown	(12) 92.3	-- --	(1) 7.7
	1-3	Gross	(9) 75.0	(3) 25.0	-- --
		Unknown	(6) 100.0	-- --	-- --
	4-7	Gross	(3) 42.9	(4) 57.1	-- --
		Unknown	(4) 80.0	-- --	(1) 20.0
Unknown	1-7	Gross	(72) 86.7	(11) 13.3	-- --
		Unknown	(641) 93.7	(34) 5.0	(9) 1.3
	1-3	Gross	(41) 78.9	(11) 21.1	-- --
		Unknown	(497) 96.0	(19) 3.7	(2) 0.4
	4-7	Gross	(22) 100.0	-- --	-- --
		Unknown	(118) 84.2	(15) 10.7	(7) 5.0

Table 14. Dichotomized Injury Levels for Safety Seats* by Type of Use and Crash Severity.

		Injury Level			
TAD Severity	Type of Use/ Misuse	None/Slight		Moderate/Severe/Fatal	
		(N)	Row%	(N)	Row %
All**	Proper	(455)	95.6	(21)	4.4
	Gross	(121)	92.4	(10)	7.6
	Partial	(839)	92.2	(71)	7.8
	Unknown	(177)	93.1	(13)	6.9
1-3	Proper	(342)	97.4	(9)	2.6
	Gross	(92)	93.9	(6)	6.1
	Partial	(656)	95.1	(34)	4.9
	Unknown	(104)	92.0	(9)	8.0
4-7	Proper	(73)	88.0	(10)	12.0
	Gross	(33)	89.2	(4)	10.8
	Partial	(160)	84.2	(30)	15.8
	Unknown	(41)	95.3	(2)	4.7

*"Non-Crash Tested and "Unknown" Seat Types excluded.

**TAD "1-3" plus "4-7" may not total "All" TADS due to missing TAD ratings.

by necessity, excluded from the "All Types" summary. This exclusion should be considered while interpreting the data presented in this table.

When all types of crash-tested seats of a known type are considered as a whole across all levels of crash severity, it can be seen that the properly used seats work well to prevent injuries or managing to keep them at a very low level. The improperly used seats tend to allow more of the moderate to serious injuries. Among those crash tested seats where the type of proper/improper usage was known, properly used safety seats show a severe head/fatal injury rate of 0.8 percent. In contrast, this rate doubled to 1.5 percent for the grossly misused seats but decreased to 0.2 percent for partially misused seats. Due to the high number of seats of unknown type and usage and large number of serious injuries among those seats, no clear differentiation between properly, partially, and grossly misused seats can be made. In order to determine the significance of the results of the "All Types" summary, a log linear categorical model was fitted to the data with injury rates further collapsed into none/slight and moderate/severe/fatal categories. As shown in Table 14, for all levels of crash severity, properly used seats showed a moderate/severe/ fatal injury rate of 4.4 percent. These rates were 7.6 percent for grossly misused seats, 7.8 percent for partially used seats and 6.9 percent for seats of unknown usage. For all types of seats combined, this log linear model indicates that the differences between usage types ($X^2 = 10.12$, $p < .02$) and crash severity ($X^2 = 5.36$, $p < .03$) are both statistically significant. Among those safety seats where the type of proper/improper usage was known, both partial and gross misuse of the seats increased the risk of moderate to severe and fatal injuries to children by 75 percent.

When the different types of seats are looked at separately, it can be seen that the general trend for the different seat types is for the properly used seats to show a higher proportion of none or slight injuries and a smaller proportion of moderate injuries. The severe head and fatal injuries are so spread out among the different types of seats that no trends can be established.

Table 15 shows the mechanisms that produced the injuries experienced by the children riding in crash tested safety seats. As in Tables 13 and 14, non-crash tested and unknown types of seats have been excluded from the "All Types" category. Injury producing mechanisms have been divided into five categories for those children for whom the mechanism was known. These are divided into "No Injury," "Striking" where the child struck some part of the vehicle's interior, "Being Struck" where the child was held in place but was struck by flying glass or some object or another occupant being thrown around the vehicle, "Restraint" where the child was injured by contact with the restraint system or just the force of the impact, or "Intrusion" where injury was due to intrusion into the passenger compartment. The categories of "Striking" and "Restraint" can be thought of as injury mechanisms that the seats are designed to prevent while "Being Struck" and "Intrusion" are mechanisms that are for the most part beyond the control of a restraint system. No children in safety seats were ejected from the vehicle. Overall, there were 278 cases from Table 13 where the injury producing mechanism was not known.

For all types of known, crash tested seats, 95.6 percent of the children in properly used seats received no injuries. For those who were, most were struck by flying objects and glass or contacted the seat itself. A few were still able to strike the vehicle's interior and one child was injured by intrusion. Children in grossly misused seats showed a distribution of mechanisms very similar to properly used seats while those in partially misused seats were more likely to be injured by striking the interior or by contacting the restrant. Again, more confidence could be placed in these results with less missing data. The same general trends found for all types of seats tend to hold up across the different types of safety seats.

It should be pointed out here that the child who was injured by intrusion was the only properly restrained fatality in this sample. This child was in a properly used (as well as could be determined) five point harness convertible seat in the center rear of a mid-sized car and was killed when a logging truck struck the car in the side of the rear passenger compartment. Another properly restrained child received severe head injuries when the vehicle seat came loose and allowed the safety seat to flip over causing the child to strike his head on the floorboard. These two cases were beyond the ability of safety seats to manage the crash dynamics and protect the children and greatly reduced the overall performance of properly used safety seats in comparison to improperly used seats. However, since these injuries did occur to properly restrained children, they must be included in the sample. In all likelihood, if more complete information had been obtained such that the missing data could have been analyzed, these two unusual cases would not have effected the results to

Table 15. Injury Producing Mechanisms for Different Types of Seats Controlling for Proper/Improper Usage.

		Injury Producing Mechanism				
Seat Type	Type/ Use Misuse	No Injury (N) Row %	Striking (N) Row %	Being Struck (N) Row %	Restraint (N) Row %	Intrusion (N) Row %
All Types*	Proper	(398) 95.6	(4) 1.0	(6) 1.4	(7) 1.7	(1) 0.2
	Gross	(120) 96.0	(2) 1.6	(0) 0.0	(3) 2.4	-- --
	Partial	(765) 91.5	(27) 3.2	(16) 2.8	(28) 3.3	-- --
	Unknown	(42) 93.4	(6) 3.9	(1) 0.7	(3) 2.0	(0) --
IC	Proper	(99) 98.0	-- --	(2) 2.0	-- --	-- --
	Gross	(56) 100.0	-- --	-- --	-- --	-- --
	Partial	(82) 87.2	(6) 6.4	(4) 4.3	(2) 2.1	-- --
	Unknown	(20) 95.2	(1) 4.8	-- --	-- --	-- --
CI	Proper	(49) 98.0	-- --	(1) 2.0	-- --	-- --
	Gross	(5) 62.5	-- --	-- --	(3) 37.5	-- --
	Partial	(87) 93.6	-- --	-- --	(6) 6.5	-- --
	Unknown	(30) 100.0	-- --	-- --	-- --	-- --
C5	Proper	(53) 94.6	-- --	(2) 3.6	-- --	(1) 1.8
	Gross	(16) 94.1	(1) 5.9	-- --	-- --	-- --
	Partial	(83) 91.2	(4) 4.4	(1) 1.1	(3) 3.3	-- --
	Unknown	(29) 96.7	-- --	-- --	(1) 3.3	-- --
CH+S	Proper	(43) 93.5	(3) 6.5	-- --	-- --	-- --
	Gross	(15) 100.0	-- --	-- --	-- --	-- --
	Partial	(120) 89.6	(4) 3.0	(5) 3.7	(5) 3.7	-- --
	Unknown	(3) 75.0	-- --	-- --	(1) 25.0	-- --

(Continued)

*"Non-Crash Tested" and "Unknown" Seat Types excluded.

Table 15. Continued.

Seat Type	Type/ Use Misuse	No Injury (N)	No Injury Row %	Injury Producing Mechanism: Striking (N)	Striking Row %	Being Struck (N)	Being Struck Row %	Restraint (N)	Restraint Row %	Intrusion (N)	Intrusion Row %
CH/S	Proper	(81)	93.1	(1)	1.2	--	--	(5)	5.8	--	--
	Gross	(3)	100.0	--	--	--	--	--	--	--	--
	Partial	(50)	96.2	(1)	1.9	--	--	(1)	1.9	--	--
	Unknown	(32)	86.5	(4)	10.8	(1)	2.7	--	--	--	--
CT	Proper	(20)	90.9	--	--	--	--	(2)	9.1	--	--
	Gross	(20)	100.0	--	--	--	--	--	--	--	--
	Partial	(254)	90.4	(10)	3.6	(6)	2.1	(11)	3.9	--	--
	Unknown	(21)	95.5	--	--	--	--	(1)	4.6	--	--
TOD	Proper	(19)	100.0	--	--	--	--	--	--	--	--
	Gross	--	--	--	--	--	--	--	--	--	--
	Partial	(22)	100.0	--	--	--	--	--	--	--	--
	Unknown	(2)	100.0	--	--	--	--	--	--	--	--
BH	Proper	(10)	90.9	--	--	(1)	9.1	--	--	--	--
	Gross	(5)	83.3	(1)	16.7	--	--	--	--	--	--
	Partial	(50)	100.0	--	--	--	--	--	--	--	--
	Unknown	--	--	--	--	--	--	--	--	--	--
BS	Proper	(24)	100.0	--	--	--	--	--	--	--	--
	Gross	--	--	--	--	--	--	--	--	--	--
	Partial	(17)	89.5	(2)	10.5	--	--	--	--	--	--
	Unknown	(5)	83.3	(1)	16.7	--	--	--	--	--	--
Non-Crash Tested	Gross	(10)	58.8	(7)	41.2	--	--	--	--	--	--
	Unknown	(10)	90.9	(1)	9.1	--	--	--	--	--	--
Unknown	Gross	(63)	86.3	(1)	1.4	(1)	1.4	(8)	11.0	--	--
	Unknown	(586)	91.6	(16)	2.5	(18)	2.8	(19)	3.0	(1)	0.2

the extent that they did, but their inclusion helps to provide a conservative "real world" estimate of safety seat effectiveness.

One concern that child safety advocates have had has been the possible loss of effectiveness for seats requiring a tether when the tether is not used. Based on this sample of crashes, it appears that the nonuse of a tether on those seats requiring one does not greatly diminish their effectiveness. Among those children in convertible seats requiring a tether strap, 90.4 percent were uninjured when the seats were misused. This is no different from the 90.9 percent of the children who were uninjured when the seats were properly used. There were 3.6 percent of the children in misused tethered seats who were injured by striking the vehicle's interior, but the proportion is not as great as might have been expected based on laboratory testing of tethered seats in misuse modes. This is not to say, however, that it is safe not to use the tether. The great majority of misused tether models were in low severity crashes but in the higher severity crashes, only 74 percent of the 47 children in misused tethered seats were uninjured and 13 percent struck the vehicle. There were only two children in properly used tethered seats in severe crashes (both injured by contact with the restraint) so the misuse and proper modes cannot really be compared for severe crashes.

In summary, the data that is available does reinforce the importance of using safety seats properly. Children in properly used seats are more likely to be uninjured or receive minor injuries than are children in improperly used safety seats. In addition, children in improperly used seats are more likely to receive their injuries in ways that the seats were designed to prevent, than are children in properly used seats.

Injury Producing Mechanisms Associated with Lap Held Children

It has generally been acknowledged that holding a child on one's lap is a very dangerous practice. Crash tests have shown that lap held children can be crushed by unrestrained adults and that restrained adults do not have the strength to hold onto a child even in a moderate crash. In order to examine the mechanisms associated with lap held children, this accident data has been examined for lap held children as a separate group. Table 16 shows the distribution of mechanisms producing injuries to lap held children. From the bottom "Total" row, it can be seen that 89 percent of the lap held children were not injured. This compares unfavorably to 95.5 percent of the children in

Table 16. Injury Producing Mechanisms for Lap Held Children by Seating Position.

	Injury Producing Mechanism					
Seating Position	Uninjured Row%/(N)	Striking Row%/(N)	Being Struck Row%/(N)	Ejection Row%/(N)	Missing	Total Col %/(N)
Front Center	86.8 (33)	5.3 (2)	2.6 (1)	5.3 (2)	(4)	4.3 (38)
Front Outboard	87.4 (594)	8.8 (60)	2.4 (16)	1.5 (10)	(49)	76.2 (680)
Rear Center	100.0 (21)	-- --	-- --	-- --	(5)	2.4 (21)
Rear Outboard	95.5 (147)	4.5 (7)	-- --	-- --	(9)	17.3 (154)
Total Front	87.3 (627)	8.6 (62)	2.4 (17)	1.7 (12)	(53)	80.4 (718)
Total Rear	96.0 (168)	4.0 (7)	-- --	-- --	(14)	19.6 (175)
Total	89.0 (795)	7.7 (69)	1.9 (17)	1.3 (12)	(67)	100.0 (893)

*Missing not included in percentages.

properly used safety seats who were not injured (Table 15) as well as the 92.7 percent of the children in a safety seat uninjured regardless of type of usage. As would be expected, most of the lap held children who were injured struck some part of the vehicle's interior. When the different seating positions are compared, it can be seen that the front seat is much more dangerous for lap held children than is the rear seat. Eighty seven percent of the children held in the front seat received no injuries whereas 96 percent of those in the rear seat were uninjured. Furthermore, the children in the front seat were more likely to receive injuries from being struck by other occupants or by being ejected from the vehicle. No rear seated lap held children received their injuries from these sources. A comparison of the center versus outboard positions is not possible due to the small number of lap held children in the center positions.

Table 17 examines the injury producing mechanisms for lap held children while controlling for age. A quick glance shows that there are large differences between the proportions of children being held in the front seat for different ages. For those children less than one year of age, 74 percent were held in the front seat whereas 90 percent of the three year olds were lap held in the front. With the exception of the two year olds who were in the front only 71 percent of the time, the trend would appear to be that the older the child, the more likely he or she is to be lap held in the front. Why this would be the case is hard to speculate on but regardless of the reason, it is evident that the front seat is more dangerous for lap held children of any age. In this sample, the three year olds had the lowest overall proportion of uninjured lap held children primarily due to their high proportion of front seat positioning. The two year olds, with their low proportion of front seat positioning, had the highest rate of no injuries. It can also be seen that the predominant injury producing mechanism, regardless of age or seating position, is that of striking some part of the vehicle's interior. There were no ejections among the infants less than one, but for the older children this is a significant problem.

Table 18 shows the actual injury distribution for lap held children. This table indicates that, as would be expected based on injury mechanisms, the front center position is the most dangerous position for a lap held child. Whereas the other positions show large increases in serious injury rates when comparing more severe crashes to less severe ones, there is no difference for the front center. Children lap held in this position are as likely to be seriously injured or killed in low severity crashes as they are in more severe crashes.

Table 17. Injury Producing Mechanisms for Lap Held Children by Seating Position and Age.

	Seating Position	Uninjured	Striking	Being Struck Row %/(N)	Ejection	Missing*	Total
<1	Front	88.1 (118)	11.2 (15)	0.7 (1)	-- --	(9)	74.0 (134)
	Rear	95.7 (45)	4.3 (2)	-- --	-- --	(2)	26.0 (47)
	Total	90.1 (163)	9.4 (17)	0.6 (1)	-- --	(11)	20.3 (181)
1	Front	86.6 (194)	10.3 (23)	0.9 (2)	2.2 (5)	(9)	83.3 (224)
	Rear	95.6 (43)	4.4 (2)	-- --	-- --	(6)	16.7 (45)
	Total	88.1 (237)	9.3 (25)	0.7 (2)	1.9 (5)	(15)	30.1 (269)
2	Front	92.7 (139)	4.0 (6)	1.3 (2)	2.0 (3)	(12)	71.4 (150)
	Rear	98.3 (59)	1.7 (1)	-- --	-- --	--	28.6 (60)
	Total	94.3 (198)	3.3 (7)	1.0 (2)	1.4 (3)	(12)	23.5 (210)
3	Front	83.8 (176)	8.6 (18)	5.7 (12)	1.9 (4)	(23)	90.1 (210)
	Rear	91.3 (21)	8.7 (2)	-- --	-- --	(6)	9.9 (23)
	Total	84.6 (197)	8.6 (20)	5.2 (12)	1.7 (4)	(29)	26.1 (233)
	Total	89.0 (795)	7.7 (69)	1.9 (17)	1.3 (12)	(67)	(893)

*Missing not included in percentages.
**Column "Totals" percentaged between age groups.

Table 18. Injury Levels for Lap Held Children by Seating Position and Crash Severity.

		Injury Level				
TAD	Position	None/Slight Row% (N)	Moderate Row% (N)	Severe Head/ Fatal Row% (N)	Missing*	Total Col% (N)
All TADs**	Front Ctr.	82.9 (34)	7.3 (3)	9.8 (4)	(1)	4.4 (41)
	Front Out.	87.2 (625)	9.3 (67)	3.5 (25)	(12)	76.2 (717)
	Rear Ctr.	100.0 (21)	-- --	-- --	(5)	2.2 (21)
	Rear Out.	95.1 (154)	3.1 (5)	1.9 (3)	(1)	17.2 (162)
	Total	88.6 (834)	8.0 (75)	3.4 (32)	(19)	100.0 (941)
1-3	Front Ctr.	76.5 (13)	11.8 (2)	11.8 (2)	(1)	3.1 (17)
	Front Out.	92.9 (390)	6.7 (28)	0.5 (2)	--	75.8 (420)
	Rear Ctr.	100.0 (16)	-- --	-- --	(5)	2.9 (16)
	Rear Out.	97.0 (98)	2.0 (2)	1.0 (1)	--	18.2 (101)
	Total	93.3 (517)	5.8 (32)	0.9 (5)	(6)	100.0 (554)
4-7	Front Ctr.	88.9 (16)	-- --	11.1 (2)	--	6.0 (18)
	Front Out.	78.5 (175)	13.9 (31)	7.6 (17)		74.6 (223)
	Rear Ctr.	100.0 (5)	-- --	-- --	--	1.7 (5)
	Rear Out.	92.5 (49)	3.8 (2)	3.8 (2)	(1)	17.7 (53)
	Total	81.9 (245)	11.0 (33)	7.0 (21)	(1)	100.0 (299)

*Missing not included in statistics.

**TADs 1-3 and 4-7 do not total All TADs due to inclusion of Unknown TADs in All TAD Category.

In summary, this data shows that for all seating positions and levels of crash severity combined, children who were lap held at the time of the crash were more likely to be injured than were children in safety seats. The front seat, especially the front center, is the most dangerous location for being lap held. Since adults holding a child cannot protect them, those children are at an increased risk of being injured by striking the vehicle's interior or by ejection from the vehicle.

Injury Producing Mechanisms Associated with Safety Belt Use

The issue of the effectiveness of safety belts for children is very important to examine since many state child restraint laws allow safety belt usage as a substitute for safety seats. Child safety advocates routinely advise parents to secure their children larger than 20 pounds in safety belts when no safety seats are available. Fourteen percent of the children in this sample were reported to be restrained by a safety belt at the time of the crash. In general, it appears that safety belts managed to protect these children very well. Table 19 shows the mechanisms that produced injuries among safety belted children.

A very quick glance at Table 19 clearly indicates that safety belts prevent injuries better in the rear seat than in the front. Safety belted children in the front were uninjured 90.5 percent of the time whereas those in rear seating positions were uninjured 95.7 percent of the time. With the exception of the children less than one, for which there are too few safety belted children for meaningful comparisons, this same trend holds true for all ages of children as well. The reason for this is apparent when the injury mechanisms are examined. For the front seating positions, the predominant cause of the children's injuries were by the child striking some part of the vehicle, presumably the dashboard or the door for those in the outboard position. In contrast, only a few of those children in the rear were injured by contact with the vehicle but instead were more likely to be injured by contact with the safety belt itself. Again, these trends hold true across all ages of children.

Table 20 examines injury producing mechanisms for safety belted children while taking crash severity into account. For both the less severe (TAD 1-3) accidents and the more severe (TAD 4-7) accidents, the front seat continues to be a more dangerous place for safety belted children with a higher proportion of the children in the front striking the vehicle. As would be expected, injury rates are higher for safety belts in more severe accidents. Fortunately, most

Table 19. Injury Producing Mechanisms for Children Restrained by Safety Belts.

		Injury Producing Mechanism										
Age	Seating Position	Uninjured		Striking		Being Struck		Restraint		Missing*	Total**	
		Row%	(N)	Row%	(N)	Row%	(N)	Row%	(N)		Col%	(N)
All	Front Ctr.	93.1	(134)	6.3	(9)	0.7	(1)	--	--	(14)	15.5	(144)
	Front Out.	89.3	(266)	6.7	(20)	1.7	(5)	2.3	(7)	(22)	32.1	(298)
	Rear Ctr.	96.0	(72)	--	--	--	--	4.0	(3)	(6)	8.1	(75)
	Rear Out.	95.6	(394)	1.2	(5)	0.5	(2)	2.7	(11)	(15)	44.3	(412)
	Total	93.2	(866)	3.7	(34)	0.9	(8)	2.3	(21)	(57)	100.1	(929)
0	Front Ctr.	100.0	(5)	--	--	--	--	--	--	--	33.3	(5)
	Front Out.	100.0	(5)	--	--	--	--	--	--	--	33.3	(5)
	Rear Ctr.	--	--	--	--	--	--	--	--	--	--	--
	Rear Out.	80.0	(4)	20.0	(1)	--	--	--	--	(1)	33.3	(5)
	Total	93.3	(14)	6.7	(1)	--	--	--	--	(1)	1.6	(15)
1	Front Ctr.	82.9	(29)	17.1	(6)	--	--	--	--	(11)	24.1	(35)
	Front Out.	93.2	(41)	6.8	(3)	--	--	--	--	(5)	30.3	(44)
	Rear Ctr.	100.0	(5)	--	--	--	--	--	--	--	3.4	(5)
	Rear Out.	98.4	(60)	--	--	--	--	1.6	(1)	(6)	42.1	(61)
	Total	93.1	(135)	6.2	(9)	--	--	0.7	(1)	(22)	15.6	(145)
2	Front Ctr.	98.3	(58)	1.7	(1)	--	--	--	--	(2)	18.7	(59)
	Front Out.	86.7	(91)	7.6	(8)	1.0	(1)	4.8	(5)	(10)	33.2	(105)
	Rear Ctr.	92.9	(26)	--	--	--	--	7.1	(2)	(2)	8.9	(28)
	Rear Out.	93.5	(116)	2.4	(3)	--	--	4.0	(5)	(6)	39.2	(124)
	Total	92.1	(291)	3.8	(12)	0.3	(1)	3.8	(12)	(20)	34.0	(316)
3	Front Ctr.	93.3	(42)	4.4	(2)	2.2	(1)	--	--	(1)	9.9	(45)
	Front Out.	89.6	(129)	6.3	(9)	2.8	(4)	1.4	(2)	(7)	31.8	(144)
	Rear Ctr.	97.6	(41)	--	--	--	--	2.4	(1)	(4)	9.3	(42)
	Rear Out.	96.4	(214)	0.5	(1)	0.9	(2)	2.3	(5)	(2)	49.0	(222)
	Total	94.0	(426)	2.7	(12)	1.6	(7)	1.8	(8)	(14)	48.8	(453)

*Missing not included in statistics.
**Column "Totals" percentaged between age groups.

Table 20. Injury Producing Mechanisms for Children Restrained by Safety Belts Controlling for Crash Severity.

			Injury Producing Mechanism										
Age	TAD	Seating Position	Uninjured Row%	(N)	Striking Row%	(N)	Being Struck Row%	(N)	Restraint Row%	(N)	Missing*	Total** Col%	(N)
All	1-3	Front	93.1	(339)	5.5	(20)	0.8	(3)	0.5	(2)	(14)	46.6	(364)
		Rear	96.7	(407)	0.5	(2)	0.2	(1)	2.6	(11)	(13)	53.4	(421)
	4-7	Front	78.4	(40)	15.7	(8)	5.9	(3)	--	--	(11)	55.4	(51)
		Rear	87.2	(34)	5.1	(2)	2.6	(1)	5.1	(2)	(5)	44.6	(39)
0	1-3	Front	100.0	(8)	--	--	--	--	--	--	--	72.7	(8)
		Rear	100.0	(3)	--	--	--	--	--	--	(1)	27.3	(3)
	4-7	Front	100.0	(2)	--	--	--	--	--	--	--	100.0	(2)
		Rear	--	--	--	--	--	--	--	--	--	0.0	--
1	1-3	Front	97.1	(66)	2.9	(2)	--	--	--	--	(3)	53.1	(68)
		Rear	100.0	(60)	--	--	--	--	--	--	(2)	46.9	(60)
	4-7	Front	30.0	(3)	70.0	(7)	--	--	--	--	(3)	76.9	(10)
		Rear	66.7	(2)	--	--	--	--	33.3	(1)	(4)	23.1	(3)
2	1-3	Front	93.2	(124)	6.0	(8)	0.8	(1)	--	--	(8)	49.4	(133)
		Rear	94.1	(127)	0.7	(1)	--	--	5.2	(7)	(5)	50.6	(135)
	4-7	Front	95.5	(21)	4.5	(1)	--	--	--	--	(3)	68.8	(22)
		Rear	80.0	(8)	20.0	(2)	--	--	--	--	--	31.3	(10)
3	1-3	Front	91.0	(141)	6.5	(10)	1.3	(2)	1.3	(2)	(3)	41.0	(155)
		Rear	97.3	(217)	0.4	(1)	0.4	(1)	1.8	(4)	(5)	59.0	(223)
	4-7	Front	82.4	(14)	--	--	17.6	(3)	--	--	(5)	39.5	(17)
		Rear	92.3	(24)	--	--	3.8	(1)	3.8	(1)	(1)	60.5	(26)

*Missing not included in statistics.
**Percentaged within each TAD category.

Table 21. Injury Producing Mechanisms for Children Restrained by Safety Belts by Weight and Crash Severity.

		Injury Producing Mechanisms										
Weight	TAD	Uninjured		Striking		Being Struck		Restraint		Missing*	Total**	
		Row%	(N)	Row%	(N)	Row %	(N)	Row%	(N)		Col%	(N)
<20	All	95.5	(21)	4.5	(1)	-	-	-	-	(1)	2.8	(22)
	1-3	100.0	(18)	-	-	-	-	-	-	(1)		(18)
	4-7	100.0	(2)	-	-	-	-	-	-	-		(2)
20-29	All	90.1	(255)	5.3	(15)	0.4	(1)	4.2	(12)	(31)	35.5	(283)
	1-3	93.5	(229)	3.7	(9)	0.4	(1)	2.4	(6)	(23)		(245)
	4-7	69.6	(16)	26.1	(6)	-	-	4.3	(1)	(7)		(23)
30-39	All	94.5	(376)	2.8	(11)	1.0	(4)	1.8	(7)	(15)	49.9	(398)
	1-3	96.0	(316)	1.8	(6)	0.6	(2)	1.5	(5)	(11)		(329)
	4-7	82.2	(37)	8.9	(4)	4.4	(2)	4.4	(2)	(4)		(45)
40-49	All	95.8	(68)	2.8	(2)	1.4	(1)	-	-	(5)	8.9	(71)
	1-3	96.9	(62)	3.1	(2)	-	-	-	-	-		(64)
	4-7	83.3	(5)	-	-	16.7	(1)	-	-	(5)		(6)
50+	All	78.3	(18)	21.7	(5)	-	-	-	-	-	2.9	(23)
	1-3	78.3	(18)	21.7	(5)	-	-	-	-	-		(23)
	4-7	-	-	-	-	-	-	-	-	-		-
Total	All	92.6	(738)	4.3	(34)	0.8	(6)	2.4	(19)	(51)	100.0	(797)
	1-3	94.7	(643)	3.2	(22)	0.4	(3)	1.6	(11)	(34)		(679)
	4-7	78.9	(60)	13.2	(10)	3.9	(3)	3.9	(3)	(16)		(76)

*Missing data not included in percentages.
**Totals for 1-3 and 4-7 do not add up to total for "All" due to missing TADS.

of these children (89 percent) were involved in less severe accidents when the crash severity was known. The small number of children in the more severe crashes makes it difficult to draw meaningful conclusions about safety belt performance for the different age groups in the high severity crashes.

Table 20 takes a further look at safety belt usage for children by comparing weight ranges rather than age groups. Ninety-four percent of the sample fell into the weight range of 20 to 49 pounds. Among these children, there is a trend towards fewer injuries for heavier children. Whereas 90.1 percent of the 20 pounders were uninjured, 94.5 percent of the 30 pounders and 95.8 percent of the 40 pounders were uninjured. The low number of less than 20 and over 50 pounders does not permit conclusions to be drawn about their actual injury experience. The 20 pounders are more likely to be injured by striking the vehicles' interior. Perhaps the larger children can brace themselves a little better in minor crashes. The 20 pounders also are more likely to be injured by the belt itself. Whether this is due to their smaller bodies not withstanding forces as well or due to incorrect fit of the belt is not known.

As can be seen in this table, the children restrained by safety belts were also predominantly (87 percent) in lower severity crashes. As with the analysis by age, the number of children in higher severity crashes within each weight range are very small, but the numbers that are available do show that for the children 20-49 pounds, those in lower severity crashes are much less likely to be injured than those in the more severe crashes and it does appear that the heavier children are better protected by safety belts in both low and high severity crashes than are the smaller children.

In summary, this data indicates that safety belts can provide very good protection for children. When compared to injury producing mechanisms for children in safety seats (Table 15), safety belts are not as effective as properly used safety seats in terms of preventing injuries. Safety belts allow more children to strike the vehicles' interior than do properly used safety seats and they produce more injuries from contact with the restraint system itself. On the other hand, safety belts compare favorably, if not better, with grossly and partially misused safety seats both in terms of preventing injuries and in terms of the mechanisms associated with those injuries that do occur.

Comparison of the Effectiveness of Safety Belts Versus Correctly and Incorrectly Used Safety Seats

Thus far, the available data has been analyzed to determine the injury producing mechanisms for various restraint modes and lap held children. At this point, analysis will turn to an examination of the levels of injuries experienced by these children. Table 22 compares the injury distributions for unrestrained children and those restrained by various modes. With the exception of non-crash tested seats, all modes of restraints performed better than did no restraint in terms of preventing injuries or keeping injuries very minor. As might be expected, properly used safety seats performed the best for preventing injuries.

At the other end of the injury distribution, 2.74 percent of the unrestrained children received serious head or fatal injuries. Safety belts were able to reduce this proportion by better than half, lap belts showed a serious head/fatal injury rate of 1.25 for a 54 percent reduction and lap and shoulder combination reduced this rate by 59 percent to 1.13. Among the safety seats in use, the properly used seats reduced the severe head/fatal injury rate by 69 percent to 0.84. It should be noted again that this rate includes at least three cases in which the injuries were beyond the control of the seat involved. Besides the previously discussed unsurvivable accident and the accident where the vehicle rear seat detached, a third serious head injury was caused by a flying object striking the child. The injury producing mechanism for the fourth case is unknown. The grossly misused safety seats had a severe head/fatal injury rate of 1.53, almost double the rate as for properly used seats. Interestingly, the partially misused seats had the lowest severe head/fatal injury rate of all modes including the properly used seats. Out of a total of eighteen for all seats, there were ten severe head/fatal injuries to children in safety seats where their proper/improper use could not be determined. If these seats could have been classified, they could have greatly changed the rates for the different seats. Due to the low numbers of severe head and fatal injuries, injury rates were also computed for "Moderate" and "Severe Head/Fatal" injuries combined. The moderate to fatal injury rate for unrestrained children is 13.83 percent. Lap belts reduced this rate by 43 percent and for lap and shoulder belts there was a 32 percent reduction. The largest moderate to fatal injury reduction, 68 percent, was for properly used safety seats. Reductions for grossly and partially misused seats were nearly identical, 45 and 44 percent, respectively. Seats of unknown usage reduced these injuries by 47 percent and there was a 65 percent increase in moderate to fatal injuries for the few non-crash tested seats in the sample.

Based on this data that is available for analysis, it does appear that overall, even grossly and partially misused seats are effective in preventing

Table 22. Comparison of Effectiveness Levels for Different Restraint Modes.

			Injury Level		Restraint Effectiveness Estimates	
Restraint	Total Col.% (N)	Moderate Row% (N)	Severe Head/ Fatal Row% (N)	Mod/Sev/ Fatal Row% (N)	Severe Head/ Fatal	Mod/Sev/ Fatal
None	52.2 (3724)	11.1 (413)	2.74 (102)	13.83 (515)	Baseline	
Lap Belt	11.3 (803)	6.6 (53)	1.25 (10)	7.85 (63)	-42.9	-43.2
Lap & Shoulder Belt	3.7 (265)	8.3 (22)	1.13 (3)	9.43 (25)	-38.5	-31.8
CR Proper	5.9 (476)	3.6 (17)	0.84 (4)	4.41 (21)	-69.3	-68.1
CR Gross Misuse	1.8 (131)	6.1 (8)	1.53 (2)	7.63 (10)	-44.2	-44.8
CR Partial Misuse	11.9 (910)	7.6 (69)	0.22 (2)	7.80 (71)	-92.0	-43.6
CR Unknown Proper	12.4 (922)	6.2 (57)	1.08 (10)	7.27 (67)	-60.6	-47.4
Non-Crash Tested	0.4 (35)	20.0 (7)	2.85 (1)	22.86 (8)	+4.0	+65.3
Total	100.0 (7265)	8.9 (646)	1.85 (133)	10.72 (779)		

*Percent difference from rate for unrestrained injury rates.

serious head and fatal injuries when compared to no restraint. They do, however, allow a much higher proportion of moderate injuries than do properly used seats. Perhaps this is because even a grossly misused seat (that is, the harness and/or the belt is not used) gets the child off the lap of another occupant. Overall, properly used safety seats seem to offer almost "all or nothing" protection. Properly used seats have both the highest proportion of none or slight injuries and the lowest proportion of moderate injuries. Unless circumstances beyond the control of the seat are present, properly used safety seats prevent injuries or at least keep them down to a minor level. Exclusion of the fatality and serious injuries to two of the children in properly used seats would have reduced the rate for properly used seats by half. If the ten unclassified seats in which children received severe head/fatal injuries could have been classified, chances are that they would have been misused to some degree.

Table 23 introduces crash severity to further differentiate the performance of various restraint modes. In general, these figures follow the trends established across all levels of crash severity. For the lower severity crashes (TAD 1-3) the unrestrained children had the lowest proportion of no or slight injuries. Less than three out of every 100 children in properly used safety seats received moderate injuries and the rest were either uninjured or received only minor injuries. In the lower severity crashes, both grossly and partially misused safety seats performed better than did no restraint at all. Safety belts also performed very well in keeping injuries minor and in preventing severe head/fatal injuries.

Examination of the rates for the more severe crashes (TAD 4-7) shows the greater danger inherent in these crashes. Fortunately, over three-fourths (77%) of the children were involved in less severe crashes. Due to the smaller proportion of children in the more severe crashes, their numbers within each restraint category are much smaller and thus meaningful trends are hard to establish.

In these severe crashes, unrestrained children received no or slight injuries 80 percent of the time. All safety seat modes had higher proportions of uninjured children, but safety belts allowed more injuries than did no restraint. All types of restraint systems, with the exception of lap belts, did however manage to keep more of the injuries that did occur to a moderate level. The severe head and fatal injury rate for lap belts was 7.4 percent as opposed to 6.7 percent for the unrestrained children. As will be shown later, this is

Table 23. Comparison of Injury Rates for Different Restraint Modes by Crash Severity.

		Injury Level				
Restraint	TAD*	None/Slight Row% (N)	Moderate Row% (N)	Severe Head/ Fatal) Row% (N)	Missing*	Total**
None	1-3	88.9 (2241)	10.2 (257)	1.0 (24)	(59)	47.9 (2522)
	4-7	80.0 (742)	13.3 (123)	6.7 (63)	(28)	58.8 (928)
Lap Belt	1-3	94.6 (645)	4.8 (33)	0.6 (4)	(9)	13.0 (682)
	4-7	74.6 (63)	18.0 (15)	7.4 (6)	(4)	5.3 (84)
Lap & Shoulder Belt	1-3	96.2 (194)	2.8 (6)	1.0 (2)	(6)	3.8 (202)
	4-7	68.7 (27)	28.1 (11)	3.2 (1)	(0)	2.5 (39)
CR Proper	1-3	97.4 (342)	2.6 (9)	0.0 (0)	(0)	6.7 (351)
	4-7	88.0 (73)	8.4 (7)	3.6 (3)	(0)	5.3 (83)
CR Gross Misuse	1-3	93.9 (92)	6.1 (6)	0.0 (0)	(3)	1.9 (98)
	4-7	87.9 (33)	6.1 (2)	6.1 (2)	(0)	2.3 (37)
CR Partial Misuse	1-3	95.1 (656)	4.8 (33)	0.1 (1)	(8)	13.1 (690)
	4-7	81.3 (160)	18.1 (29)	0.6 (1)	(0)	12.0 (190)
CR Unknown Proper	1-3	92.0 (642)	7.7 (54)	0.3 (2)	(9)	13.3 (698)
	4-7	88.3 (181)	8.3 (17)	3.4 (7)	(1)	13.0 (205)
Non-Crash Tested	1-3	83.3 (15)	16.7 (3)	0.0 (0)	(0)	0.3 (18)
	4-7	58.3 (7)	33.3 (4)	8.3 (1)	(0)	0.8 (12)
Total	1-3	91.9 (4827)	7.5 (401)	0.6 (33)	(94)	76.9 (5261)
	4-7	80.6 (1286)	14.0 (208)	5.4 (84)	(33)	23.1 (1578)

*TAD 1-3 plus 4-7 may not total all crashes in Table 21 due to missing TAD ratings.

**Missing not included in percentages.

***Column percentages are within TAD levels.

primarily due to lap belted children in the front seat where the lack of upper torso support allows head injuries. It should be noted, however, that none of these injuries were fatal for the lap belted children. The use of lap and shoulder belts decreased the likelihood of severe head and fatal injuries by 52 percent. For safety seats the reduction figures were 46 percent for properly used safety seats, 9 percent for grossly misused seats, 91 percent for partially misused safety seats and 49 percent for those seats where proper usage could not be classified. Again, it should be pointed out that the one fatality and two serious head injuries among the children in properly used safety seats were unusual circumstances.

Table 24 takes both restraint use and seating position into account. In order to maintain adequate numbers within each seating position, type of safety belts and types of seat usage have been collapsed. All types of seats, with the exception of non-crash tested seats, have been included in this category.

As can be seen, the front seat is a dangerous environment for unrestrained children and to a slightly less degree for safety belted children. There is little difference between the front center and outboard positions in the severe head/fatal injury rate for unrestrained children. Mechanisms for these injuries are present regardless of position in the front. Children in safety belts are less likely to be seriously injured in the front outboard. It appears that the value of the available shoulder belt plus being moved further away from the steering wheel counteracts possible increased danger from intrusion. Children in safety seats are less likely to be seriously injured in the center position of the front seat than they are in the outboard position. Upper torso restraint is available with a safety seat in either the center or outboard position, but the children in the outboard position are less protected from side impacts.

For unrestrained and safety belted children, the center rear position is the safest position in the vehicle. For children in safety seats, front and rear center positions perform almost equally well. In general, any rear seat position is safer than any front seat position for a given restraint mode. The exception is that for some unexplainable reason, children in safety seats in the rear outboard positions were unexpectedly more likely to be seriously injured than in either front position.

This anomaly is brought out even more in Table 25 where crash severity is also taken into account. Severe head fatal injury rates for no restraint, safety belts and safety seats are all lower for the rear seat than the front in the lower severity crashes. The same trend holds true for no restraint and

Table 24. Severe Head and Fatal Injuries by Restraint Status and Seating Position.

	All Positions*			Front Center			Front Outboard		
	Severe Head/Fatal		Total	Severe Head/Fatal		Total	Severe Head/Fatal		Tot
Restraint	%	(N)	N	%	(N)	N	%	(N)	N
None	2.73	(102)	3725	3.02	(27)	893	3.26	(46)	1409
Belt	1.22	(13)	1069	2.91	(5)	172	2.00	(7)	350
CR	0.81	(22)	2716	0.26	(1)	388	0.71	(5)	708

	Rear Center			Rear Outboard		
	Severe Head/Fatal		Total	Severe Head/Fatal		Total
Restraint	%	(N)	N	%	(N)	
None	1.29	(6)	464	2.22	(21)	944
Belt	0.00	(0)	83	0.22	(1)	462
CR	0.32	(1)	313	1.15	(15)	1307

*Separate positions may not total "All Positions" due to missing position data.

Table 25. Severe Head and Fatal Injuries by Restraint Status, Position and Crash Severity.

		All Positions*			Front			Rear		
		Severe Head/Fatal		Total	Severe Head/Fatal		Total	Severe Head/Fatal		Total
TAD	Restraint	%	(N)	N	%	(N)	N	%	(N)	N
1-3	None	1.03	(26)	2523	1.15	(17)	1480	0.68	(7)	1036
	Belt	0.68	(6)	885	1.43	(6)	420	0.00	(0)	463
	CR	0.15	(3)	2006	0.25	(2)	804	0.08	(1)	1202
4-7	None	6.79	(63)	928	7.39	(46)	636	5.61	(16)	285
	Belt	5.69	(7)	123	8.57	(6)	70	1.89	(1)	53
	CR	2.84	(15)	529	0.87	(2)	231	4.36	(13)	298

*Separate positions may not total "All Positions" due to missing position data.

**TADs 1-3 and 4-7 may not equal totals in Table 23 due to missing TAD Ratings.

Table 26. Severe Head and Fatal Injuries by Restraint Status, Seating Position and Age.

		All			Front			Rear		
		Severe Head/Fatal		Total	Severe Head/Fatal		Total	Severe Head/Fatal		Total
Age*	Restraint	%	(N)	N	%	(N)	N	%	(N)	N
0-3	None	2.73	(102)	3725	3.17	(73)	2302	1.92	(27)	1408
	Belt	1.22	(13)	1069	2.30	(12)	522	0.18	(1)	545
	CR	0.81	(22)	2716	0.55	(6)	1096	0.99	(16)	1620
<1	None	3.29	(10)	304	3.83	(8)	209	2.11	(2)	95
	Belt	0.00	(0)	18	0.00	(0)	10	0.00	(0)	8
	CR	0.95	(10)	1050	0.19	(1)	529	1.73	(9)	521
1	None	4.66	(25)	537	4.06	(17)	419	6.78	(8)	118
	Belt	2.42	(4)	165	4.44	(4)	90	0.00	(0)	75
	CR	1.00	(9)	898	1.01	(3)	296	1.00	(6)	602
2	None	1.93	(18)	932	1.81	(10)	552	2.10	(8)	380
	Belt	0.00	(0)	347	0.00	(0)	183	0.00	(0)	164
	CR	0.67	(3)	450	1.34	(2)	149	0.33	(1)	301
3	None	1.36	(23)	1692	1.89	(18)	952	0.68	(5)	740
	Belt	0.81	(4)	494	1.40	(3)	214	0.36	(1)	280
	CR	0.00	(0)	255	0.00	(0)	87	0.00	(0)	168

*Separate ages may not total age 0-3 due to missing age data.

safety belts in the more severe crashes as well with safety belts showing a very large decrease. For the safety seats, however, there is an increase in serious injury rates from 0.87 to 4.36 when the front seat is compared to the rear seat. As will be seen, this could be due to patterns of seat usage.

Table 26 examines severe head/fatal injuries for different restraint modes while looking at age as well as seating position. The overall injury rate for children in safety seats is higher for the rear than for the front. The breakdown by age may help to offer a possible explanation. The infants (age <1) in safety seats had an extremely low injury rate for the front seat in comparison to rear seat positioned infants in seats. They also had the highest proportion of seats used in the front. Table 12 indicated that infant carriers and convertible seats used for infants were less likely to be misused than were seats for toddlers (61% misuse for infants vs. 74% for toddlers) and it may be the case that infant carriers used in the front are more likely to be used correctly than in the rear. If this is the case, it may be that the large number of infants in properly used seats in the front is helping to keep the front seat injury rate down. The high injury rate for safety seated infants in the rear (plus previously discussed uncontrollable events) apparently is pushing the rear seat injury rate up.

Regardless of age, children are much better protected against serious head or fatal injuries if they are in some type of restraint system than if they are allowed to ride unrestrained. With the exception of one-year-olds who were in safety belts in the front seat, all ages of children in either safety seats or belts, front seat or back seat, received serious and fatal injuries at rates significantly lower than for unrestrained children.

Table 27 provides a summary of the effectiveness of different modes of restraint in relation to no restraint at all. For this table, the practice of holding a child on one's lap has been broken out as a type of "restraint." Thus, the no restraint category includes children unrestrained and not being held by another occupant. Across all levels of crash severity, 18.50 percent of the unrestrained children received moderate, severe or fatal injuries. This rate for lap held chidlren was reduced by 39 percent to 11.4 percent but this level of effectiveness was the lowest of the restraint modes. Lap and shoulder belts reduced injuries by 49 percent and lap belts (58%), grossly misused seats (59%), and partially misused seats (58%) all showed essentially the same level of injury reduction. Properly used safety seats reduced these injuries by 76% to 4.4%.

Table 27. Moderate to Fatal Injury Rates for Restraint Types by Crash Severity.

	All TADS*			TAD 1-3			TAD 4-7		
Restraint	N/Inj.	Inj. %	Effectiveness	N/Inj.	Inj. %	Effectiveness	N/Inj.	Inj. %	Effectiveness
None	2783 515	18.50	**	1968 244	12.40	**	629 132	20.99	**
Lap Held	941 107	11.37	-38.5	554 37	6.68	-46.1	299 54	18.06	-13.9 (NS)
Lap Belt	803 63	7.85	-57.6	682 37	5.43	-56.2	84 21	25.00	+19.1 (NS)
Lap & Shoulder Belt	265 25	9.43	-49.0	202 8	3.96	-68.1	39 12	30.80	+46.7 (NS)
CR Proper	476 21	4.41	-76.2	351 9	2.56	-79.4	83 10	12.05	-42.6 (NS)
CR Gross Misuse	131 10	7.63	-58.8	98 6	6.12	-50.6 (NS)	37 4	10.81	-48.5 (NS)
CR Partial Misuse	910 71	7.80	-57.8	690 34	4.93	-60.2	190 30	15.79	-24.8 (NS)
CR Unknown Proper	922 67	7.27	-60.7	698 50	8.02	-35.3	205 24	11.71	-44.2

*TAD 1-3 plus 4-7 may not add up to "All TADS" due to missing TADS.

**Percent difference between injury levels for unrestrained children and other restraint types. All differences are significant ($X^2 = 3.84$, $p < .05$) unless otherwise noted by "NS".

When crash severity is taken into account, the properly used seats again show the greatest effectiveness in the lower severity crashes (TAD 1-3). Lap and shoulder belts reduce injuries more than the lap belts and partially misused safety seats and lap held children show the lowest effectiveness level. The reduction for grossly misused seats is not statistically significant. None of the effectiveness estimates for the TAD 4-7 crashes are significant with the exception of the unknown usage seats. The 43 percent reduction for properly used seats is significant at the .06 level.

In summary, this data indicates that all modes of restraints are very effective in preventing injuries of any magnitude in crashes and in preventing serious head and fatal injuries in particular. Unusual circumstances led to the inclusion of one fatality and two serious head injuries among children in properly used safety seats. Even with these cases, properly used seats showed a 69 percent reduction in serious head/fatal injuries from the rate of unrestrained children. Seats classified as partially misused showed a surprising 92 percent reduction but the efffectiveness of grossly misused seats was reduced to 44 percent. Unclassified seats showed a 61 percent reduction from the serious and fatal injury rate for unrestrained children. In all probability, if these seats could have been classified as to type of use, the effectiveness levels for different types of use would have changed. Lap belts and lap/shoulder belt combinations were less effective than the seats but still showed 54 and 59 percent reductions respectively. Safety seats, no matter how used, permit virtually no serious injuries in low severe crashes. In more severe crashes, all restraints continue to provide excellent protection with the exception of lap belts. Lap belts in the front seat in severe crashes allow serious injuries at a rate comparable to no restraint. Overall, the center rear position was shown to be the safest position in a car for any given restraint mode. It does appear, however, that potential benefits that can be gained from rear seat positioning are being negated by the improper use of safety seats.

Relationship of Driver to Child and Restraint Usage

Table 28 shows the levels of restraint usage by children for differing relationships to the driver of the involved vehicle. Most of the children in this sample, 77.8 percent, were being driven by a parent. Of the remaining children, 16.5 percent were driven by a relative other than a parent and only 5.8 percent were being driven by a non-relative. This table clearly indicates that children riding with drivers other than parents were much less likely to be

Table 28. Restraint Status of Children by Their Relationship to Driver.

Relationship To Driver	Restraint Usage None Row% (N)	Belt Row% (N)	Safety Seat Row% (N)	Total Col. % (N)
Child	41.1 (2482)	17.8 (1078)	41.1 (2481)	77.8 (6041)
Relative	74.8 (960)	11.2 (144)	14.0 (179)	16.5 (1283)
Non-Relative	70.0 (317)	16.3 (74)	13.7 (62)	5.8 (453)
Total	48.3 (3759)	16.7 (1296)	35.0 (2722)	100.0 (7777)

Table 29. Restraint Status of Children < 4 by Age and Legal Status.

		Restraint Use							
		None		Safety Belt		Safety Seat		Belt or Seat	
Age	Subject to Law	Row %	(N)	Row %	(N)	Row %	(N)	%	(N)
<1	Yes	16.1	(161)	1.3	(13)	82.6	(826)	83.9	(839)
<1	No	47.8	(97)	1.5	(3)	50.7	(103)	52.2	(106)
1	Yes	23.8	(263)	10.7	(118)	65.6	(726)	76.3	(844)
1	No	65.4	(214)	13.1	(43)	21.4	(70)	34.5	(113)
2	Yes	--	--	--	--	--	--	--	--
2	No	54.4	(904)	19.9	(331)	25.7	(427)	45.6	(758)
3	Yes	--	--	--	--	--	--	--	--
3	No	68.7	(1562)	20.2	(460)	11.1	(252)	31.3	(712)

Table 30. Proper/Improper Safety Seat Usage by Relationship of Child to Driver and Injury Impact.

		Injury Level						
	Type Use/	None/Slight		Severe Head/Fatal		Total		
Relation	Misuse	Row %	(N)	Row %	(N)	Col. %*	Col %**	(N)
Child	Proper	96.2	(428)	0.5	(2)	29.4	21.0	(445)
	Gross	88.8	(158)	0.0	(0)	11.8	8.4	(178)
	Partial	92.3	(821)	0.3	(3)	58.8	42.1	(890)
	Unknown	95.0	(572)	0.5	(3)		28.5	(602)
	Total	93.6	(1979)	0.4	(8)	(1513)		(2115)
Relative	Proper	100.0	(9)	0.0	(0)	15.3	8.3	(9)
	Gross	94.1	(16)	0.0	(0)	28.8	15.7	(17)
	Partial	90.9	(30)	0.0	(0)	55.9	30.6	(33)
	Unknown	98.0	(48)	0.0	(0)		45.4	(49)
	Total	95.4	(103)	0.0	(0)	(59)		(108)
Non-Relative	Proper	75.0	(3)	0.0	(0)	44.4	16.7	(4)
	Gross	0.0	(0)	0.0	(0)	0.0	0.0	(0)
	Partial	100.0	(5)	0.0	(0)	55.6	20.8	(5)
	Unknown	46.7	(7)	0.0	(0)		62.5	(15)
	Total	62.5	(15)	0.0	(0)	(9)		(24)

protected by restraint systems. When the driver was the parent, the children were unrestrained 41 percent of the time but relatives and non-relatives left the children unrestrained 75 percent and 70 percent of the time respectively. Relative and non-relative children were 70 percent more likely to be unrestrained than were the children of the driver.

These results are not surprising. At the time these accidents occurred, North Carolina law required children to be restrained only when they were less than age two and were being driven by their parent. As shown in Table 29, those children who were subject to the law were much more likely to be buckled up than were children not subject to the law.

Table 30 shows the proportions of properly and improperly used safety seats by the child's relationship to the driver and the resulting injury impact. There were only nine safety seats used by children driven by non-relatives that could be classified as properly or improperly used and thus are not useful for comparison. A comparison of the seats used by children and other relatives of the driver show that they are partially misused nearly equally (59% partial misuse for parents vs. 56% for relatives). Seats used for children who are relatives of the driver, however, are much more likely to be grossly misused than for children of the drivers (29% for relatives vs. 12% for parents) and conversely less likely to be properly used. It is of value to note for future research purposes that the percentage of unknown usage was much higher for relatives and non-relatives of the driver than for the child of the driver. Since parents are much more familiar with their children's safety seats, they are much more likely to be able to provide the information needed for accurate proper/improper classification.

In terms of injury impact, all of the severe head/fatal injuries among these children where the relationship was known occurred among the children of the drivers. This is in all likelihood a result of their greater exposure in crashes rather than any injury patterns among properly and improperly used seats.

How Safety Seats are Acquired and Proper/Improper Usage

Table 31 shows the distribution of properly/improperly used safety seats while accounting for how the seat was acquired. Of those seats for which the method of acquisition was known, 59 percent were purchased new by the parents. Another 21 percent were given as gifts, generally new. Only 12 percent were obtained second hand either by purchase or as loans from friends or relatives.

Table 31. How Seat Was Acquired by Proper/Improper Usage and Injury Impact.

Injury Level

How Acquired	Type Use/ Misuse	No Injury		Any Injury		Total			
		Row %	(N)	Row %	(N)	Col.%	(N)	Col.%	(N)
Bought New	Proper	93.8	(243)	6.2	(16)	19.3	(259)	27.8	259
	Gross	85.6	(77)	14.4	(13)	6.7	(90)	9.7	90
	Partial	88.2	(515)	11.8	(69)	43.5	(584)	62.6	584
	Unknown	93.2	(382)	6.8	(28)	30.5	(410)	--	--
	Total	90.6	(1217)	9.4	(126)	59.8*	(1343)	59.1*	933
Bought Used	Proper	91.7	(11)	8.3	(1)	6.8	(12)	11.1	12
	Gross	86.1	(31)	13.9	(5)	20.5	(36)	33.3	36
	Partial	93.3	(56)	6.7	(4)	34.1	(60)	55.6	60
	Unknown	89.7	(61)	10.3	(7)	38.6	(68)	--	--
	Total	90.3	(159)	9.7	(17)	7.8	(176)	6.8	108
Gift	Proper	98.1	(101)	1.9	(2)	21.2	(103)	30.8	103
	Gross	85.4	(35)	14.6	(6)	8.5	(41)	12.3	41
	Partial	87.4	(166)	12.6	(24)	39.2	(190)	56.9	190
	Unknown	90.1	(136)	9.9	(15)	31.1	(151)	--	--
	Total	90.3	(438)	9.7	(47)	21.6	(485)	21.1	334
Rental	Proper	96.6	(56)	3.4	(2)	41.4	(58)	45.3	58
	Gross	100.0	(23)	0.0	(0)	16.4	(23)	18.0	23
	Partial	93.6	(44)	6.4	(3)	33.6	(47)	36.7	47
	Unknown	75.0	(9)	25.0	(3)	8.6	(12)	--	--
	Total	94.2	(132)	5.8	(8)	6.2	(140)	8.1	128
Loan from Friend/ Relative	Proper	92.9	(26)	7.1	(2)	27.5	(28)	36.4	28
	Gross	100.0	(5)	0.0	(0)	4.9	(5)	6.5	5
	Partial	95.5	(42)	4.5	(2)	43.1	(44)	57.1	44
	Unknown	88.0	(22)	12.0	(3)	24.5	(25)	--	--
	Total	96.0	(95)	4.0	(7)	4.5	(102)	4.9	77
							2246		1580

*"Total" column percentages are between types of acquisition.

An additional 6 percent were rented from various local rental programs around the state.

The proportions of new seats properly used were essentially the same for purchased seats and seats that were gifts. These rates suggest that only about 3 out of 10 parents read and follow the instructions that come with the seat. The lowest proper usage rate was for seats that were bought used. This is hardly surprising since seats often get sold without instructions. Those seats acquired on loan from a friend or relative had the second highest rate of proper usage. It appears that there is at least some instruction in the use of the seat that is passed along with the loan. The highest level of proper usage was for the seats that were rented from local programs. Whether this is due to effective instructions being provided by the rental programs or merely due to the fact that most rental programs offer infant carriers only is not known. It is interesting to note that 41 percent of all infant carriers were being used correctly as compared to the 44 percent of rental seats. Regardless of the reason, over half of the rented seats are still being improperly used. Either a substantial amount of misinformation is being transmitted through the rental procedures or more effective means of transmitting the correct information needs to be developed and utilized by rental program personnel.

In terms of injury levels, those methods of acquisition with the highest levels of improper use .. Bought New, Bought Used and Gift .. showed the highest levels for children receiving any injury. The rental and loan seats which had higher levels of proper usage also had the lower injury rates. This information shows that there is one way in which seats are acquired that could be specifically targeted for increased efforts to stimulate proper usage. Seats bought on the used market apparently do need some specific focus, but the other methods of acquisition need additional misuse countermeasures as well.

RECOMMENDATIONS

Based on the analysis of available data and the conclusions thus drawn, the following recommendations can be made.

Educational/Public Information Efforts

1) Educators should continue their efforts to stress the importance of restraint usage for children and especially to make strong efforts to counteract the practice of adults holding children on their laps in the front seat.

2) Educators should put as much emphasis as possible on efforts to encourage the proper use of safety seats and to counteract widespread misuse of seats since misuse does reduce the effectiveness of the seats.

3) Educators need to continue to encourage rear seat usage. Rear seat positioning is especially important for unrestrained and lap held children and children wearing seat belts. Where practicable, the center rear position should be used.

4) Educators need to continue to stress the importance of restraint usage even on short trips. Half of the children who were involved in accidents were within five miles of their home and severe accidents are as likely to occur close to home as on long trips.

Safety Seat Design and Manufacture

1) Designers and manufacturers of safety seats should continue efforts to simplify methods of installation and use. While easily read, understood and followed instructions should be provided with or on the seat, the assumption should be made that users will not read them. Based on this assumption, seats should be designed to be as foolproof as possible.

2) No seats should be designed to use a protective device that is separate from the rest of the system. Add-on shields were rarely used.

3) Seats should be designed to provide protection without tethers. Like add-on shields, tethers are rarely used.

Legislative Provisions

1) State legislatures should continue to require children to be restrained in cars in all seating positions. Any possible efforts to rescind child restraint laws should be vigorously opposed.

2) Child restraint laws should require proper use of safety seats and this should become a focus of enforcement efforts.

3) Child restraint laws should allow the substitution of safety belts for seats for larger children. These data indicate that where practicable, seat belt substitutions should be allowed only for children in the rear seat.

4) No exemptions based on distance from home should be allowed. Too many children become involved in accidents close to home for such exemptions to be allowed.

Future Research

1) The issue of reductions in effectiveness of safety seats when misused needs continuing analysis. Methods need to be developed to examine misuse in crashes specifically by designing methods to develop a large data base with highly reliable misuse classifications. Post facto classifications made using the available information produced large amounts of missing data.

2) More emphasis needs to be placed on obtaining data on the performance of properly versus improperly used safety seats in high severity crashes.

3) More data on the crash performance of booster seats needs to be obtained. Due to the time that the data was collected and to the focus on children less than four, relatively few booster seats were included in the sample.

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